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MINING AND MINING MACHINERY

EXPLAINING THE METHODS OF OBTAINING
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IN ALL PARTS OF THE WORLD.

BY
SYDNEY F. WALKER, R.N.
M.I.E.E., M.I.M.E., M.C.S.I.A., M.INST. M.E.
Author of "Aviation," &c.

ILLUSTRATED WITH 23 PHOTOGRAPHS AND 55 DIAGRAMS.

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PREFACE

IN the following pages the author has endeavoured to give the general reader an idea of how mining is carried on. He wishes it to be understood that the book is not designed for students in the ordinary acceptance of the term; though possibly those who are commencing the study of mining may find a perusal of its pages of assistance as an introduction to the standard mining text books. The author's idea in preparing the book has been, to give those who are interested in mining, those who may have shares in mining, and who may be surprised at the ups and downs of the values of those shares, some idea of the great uncertainty attending mining operations.

The author wishes to acknowledge his indebtedness to the Editors of *The Engineering and Mining Journal*, and *Coal Age*, of New York; *Mines and Minerals*, of Scranton, Pa.; *South African Engineering*, of London; *Iron and Coal Trades Review*; also to Mr. H. Bulmann; The Ingersoll Rand Company; The Hardy Patent Pick Company; The Jeffrey Manufacturing Company; The Sullivan Machinery Company; Messrs. Ackroyd and Best; and The C.E.A.G. Electric Lamp Company, for the illustrations that are made use of in the book.

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MINING

CHAPTER I

INTRODUCTORY

WHAT IS MEANT BY MINING

AN eminent authority gives the following definition of mining: "It is the art by which the useful minerals are obtained from the earth's crust." The latest view of modern scientists, of the birth and formation of our earth is, it and the other planets are supposed to have been formed from fragments that were thrown out from our sun at various periods. As they were forced out into space, they were given a whirling motion, which all of them have preserved; all of them settled down to a certain orbit, at varying distances from the parent sun, and all of them proceeded to cool down from the gaseous mass of which they originally consisted. After a certain very long period, a crust formed over the internal fiery mass, just as a crust may be seen to form upon a mud-bank, or upon other soft substances. The crust went on increasing in thickness; and at various periods other operations took place. The atmosphere was formed at some period of the earth's history, and at some other period there was a heavy downpour of what we now know as rain. In the process of cooling, cracks and fissures were formed in the crust; and these have since formed the valleys and hills which add so much to the beauty of our country-sides. At later periods, as the crust became thicker, the heat that was and is still present in the interior of the earth caused molten streams to force their way through

Mineral Mining

and these have led to the formation of mountains. As we have recently had reason to know, volcanic action, as the outrush of these molten streams is termed, has by no means ceased. Other processes have been continually in operation during the æons of years that have elapsed since the earth first began to take shape. Water, which is present everywhere, has had an important influence. The streams with which we are so familiar, and which again add so much to the beauty of many country-sides, bring down what geologists call "detritus": small particles of earth, of matter of various kinds which a stream has collected in its path; and at certain places, it has deposited the "detritus"; and later on, owing to some change in the direction of the stream, the mass of sediment has become solid, and later again other substances have been deposited upon it, and in course of time it has become squeezed into the substance we know as stone. The processes that have been going on to produce what are called minerals, that is to say, substances that require to be mined, are very various. In the case of coal, plants have grown upon certain sites and have died there, and been buried by "detritus" from some stream, or from a landslip, or in other ways; and in the course of ages, the plants have gradually become converted into the hard black mass we know as coal. The metals have usually been deposited in a different manner; they are very frequently found in fissures in previously formed rocks. Thus, it has happened that in the course of ages, a great thickness of slate, or some other body, has been formed, and by volcanic action, or through an earthquake, or by some other agency, fissures have been formed in the rock; and later on liquid ore has been forced up from the interior of the earth and deposited in the fissure. These deposits are known as lodes. The deposit of metals again is very various. Lodes formed in the manner just described are the most common; but large masses are frequently met with in which the ore containing the metal has found its way into something like a cave; in some cases forcing out the original occupant of the space it has taken up. In the case of mercury, it is largely found in the pores of a particular kind of sandstone. Sandstone will be familiar to everybody who has roamed

Introductory

the country-side, and as is well known, it is very porous; and consequently cinnabar, from which mercury is obtained, is easily injected into the spaces between the individual particles of the sandstone.

The number of minerals, of substances that are obtained for commercial use by mining, is very large; they include stone, clay, slate, mercury, lime, sulphur, gypsum, graphite from which lead pencils are made, petroleum, salt, coal, diamonds, rubies, and all the metals.

The depths at which the different minerals are found below the surface of the ground vary, as also the manner in which the minerals lie, and naturally the methods by which they are mined. Stone and slate lie usually on or very near the surface, though in the neighbourhood of Bath there are large stone mines, in which mining is carried out on a very large scale, quite comparable to coal mining. The great majority of stone and slate, however, is obtained by the process known as quarrying, to be described later. Minerals which lie fairly near the surface are obtained by what are called in various districts, "levels," "drifts," and in America, "daylight holes." The stone mine in the neighbourhood of Bath is a very good illustration of what the Americans would call a "daylight hole." It is practically a tunnel running into the side of the hill, the roadway being cut in the stone itself that is mined. In this case the road and the workings are all fairly on the level. In the case of some coal mines also, particularly in South Wales and in America, levels or drifts are run into the side of the mountain to meet the coal; sometimes they are on the level, and sometimes they "dip," as it is called; they incline downwards. With what the Americans call "daylight holes" the problems involved are fairly simple; but as the depth at which the mineral is found increases, the difficulties of working a "drift" increase more and more; the drift itself becomes more and more steep, and finally vertical shafts have to be adopted.

A broad distinction should here be drawn between coal mining and the great bulk of metalliferous mining. The coal lies in beds or seams; the ore from which metals are obtained is found in lodes, pockets, or masses. Coal is what

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is known as a stratified rock ; that is to say, it has assumed the form in which it now exists by pressure from above, the mass of plants from which the coal is formed being squeezed between the clay upon which usually they grew during their life and an overlying strata of some other substance. The arrangement of a coal seam between the over and underlying strata may be compared to that of the ham as it lies between the two pieces of bread in a sandwich. The coal

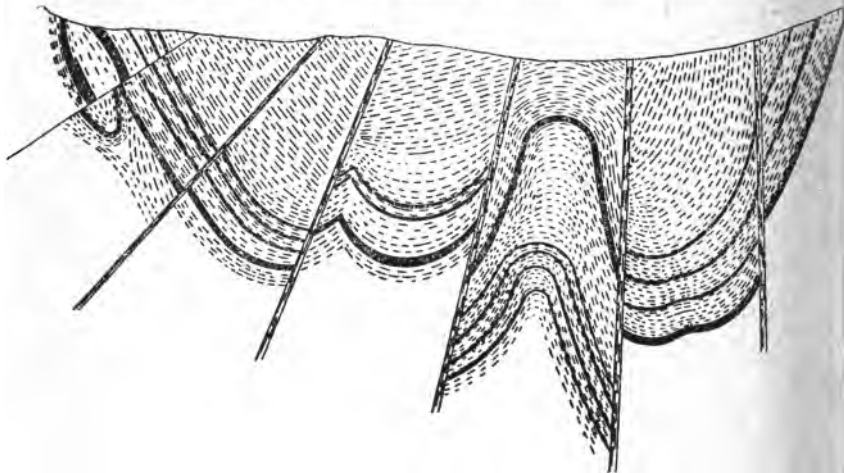


FIG. 1

Diagrammatic view of hypothetical coal-field. The view shown is what is termed a section, as though a cut were made down into the ground. The reader looks at the side of the cut. The heavy black curved lines are the coal seams, the straight lines which cut them are faults. The broken curved line represents the other strata, and the thin black line at the top the surface.

seams are usually found also in irregular basins ; the term " coal basin " is very frequently employed to denote an area in which a number of seams of coal are found. The coal basin is frequently bounded by hills on either side, and the coal seams " outcrop," as it is termed, on the hillsides, and descend to varying depths below the surface in the valleys. Fig. 1 is a diagrammatic view of a hypothetical coal-field. By " outcrop " is meant the appearance of the coal seam, or of any other strata, at the surface of the ground. Other

Introductory

strata, such as water-bearing gravels and sandstone, "outcrop" often on the side of a hill and descend from there to various depths below the surface in the lower ground adjoining. In coal basins also there are usually several seams, lying one above the other, at varying depths. According to geologists, there was a carboniferous period: a period during which the plants from which coal was afterwards formed grew in certain situations, died, and were buried; were covered up by sediment of various kinds, upon which at later periods other plants grew, which were buried in their turn, and so on. The thickness of the coal seams again varies enormously; from a few inches that cannot, except in special cases, be profitably mined, to as much as 30 feet. A common thickness for coal seams is from 3 feet to 6 feet among those that are worked in the United Kingdom and elsewhere.

The bulk of metalliferous mines, on the other hand, "outcrop," as it would be termed, in the case of coal, on the surface; and the lode descends usually at a very steep inclination, at a very small angle with a vertical line, but to very great depths. In one of the tin mines of Cornwall a depth of 3600 feet has been reached, and in the great copper mines of America, in the neighbourhood of Lake Superior, the depths are in the neighbourhood of 5000 feet. There is no "outcrop" in the case of metalliferous lodes at the other end, as there is in the case of coal seams. Fig. 2 is a diagram showing approximately the way in which metalliferous lodes lie. It can be compared with the coal basin.

In the case of coal seams and of metalliferous lodes, etc., Nature has never worked in a regular manner. The coal seams, though they average a certain thickness in any par-

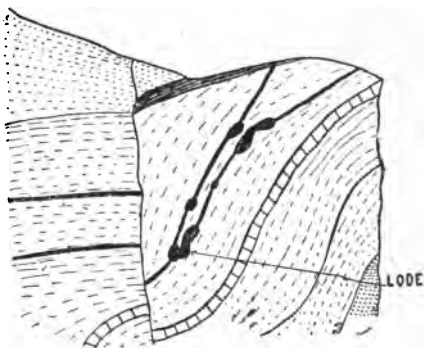


FIG. 2

Diagrammatic representation of a typical metalliferous lode. The heavy black lines, with black irregular masses, are the lodes.

Mining

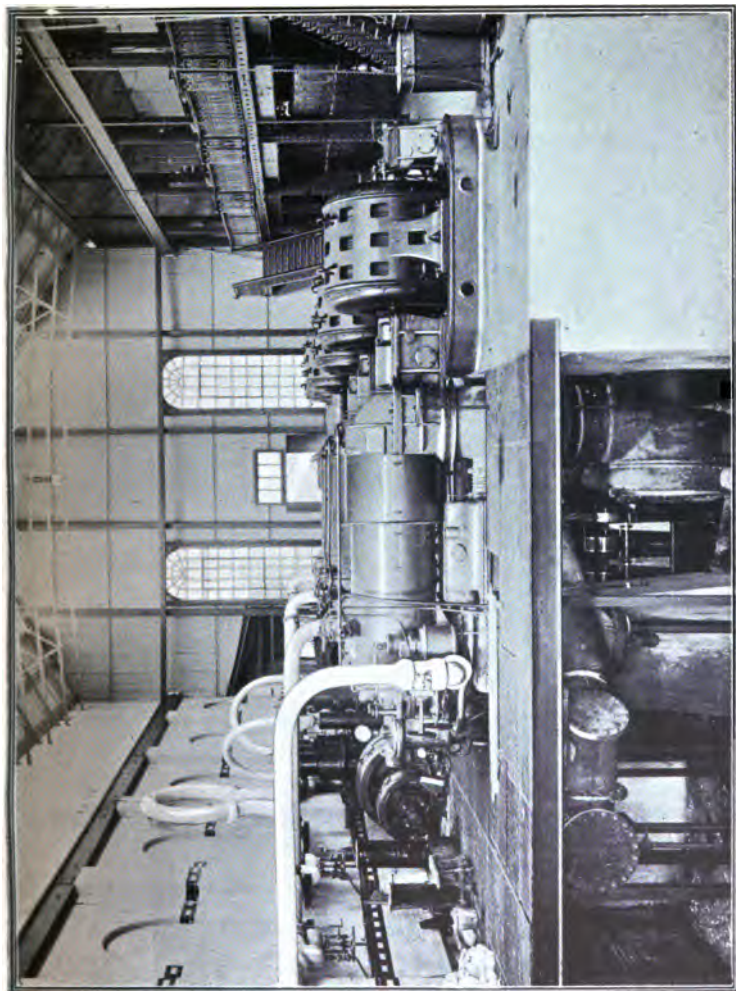
ticular mine, vary often within comparatively short distances; and again the width of the ore-bearing lodes varies even more. Nature has never been at rest, and after the coal seams have been formed, after the metalliferous lodes have been formed, she has often disturbed both of them by volcanic action. Coal seams are full of what are known as "faults," as shown in Fig. 1, and the uncertainty attending the financial working of metalliferous mines is largely due to the fact that it is never known from day to day, what is going to be met with as the work proceeds. Experienced miners know, from the hard test of practical experience, what they may probably expect; but the most experienced of them can never be sure that Nature may not have played a trick. Tin mines, for instance, and gold mines, run along ridges of hills, and it is usually safe to sink shaft after shaft along the ridge. In Cornwall, however, while this answered for a certain distance along the main ridge, there came a point where Nature had turned the ridge round, where the lode had turned upon itself, and the shaft that was sunk upon an extension of the old ridge found no ore.

In coal mining, "faults," when they are numerous, make the getting of the coal very expensive. A "fault" will throw a seam up or down by several feet, and as the "working face," as it is called, proceeds, when the "fault" is reached, it comes to a rock, in place of coal, and a considerable amount of work often has to be done to find where the coal is now to be reached. Mining engineers always know in which direction to go to look for the coal, but they do not know how far the up-throw or down-throw may be.

The art of mining, then, consists in following the mineral into the space where Nature has deposited it, extracting it with as little foreign matter, non-mineral matter, as possible, bringing it to the surface and preparing it for the market.

THE GEOGRAPHICAL DISTRIBUTION OF MINERALS

A large number of minerals are distributed pretty well all over the world. The United Kingdom for a long while held the monopoly of manufacturing, because of its coal

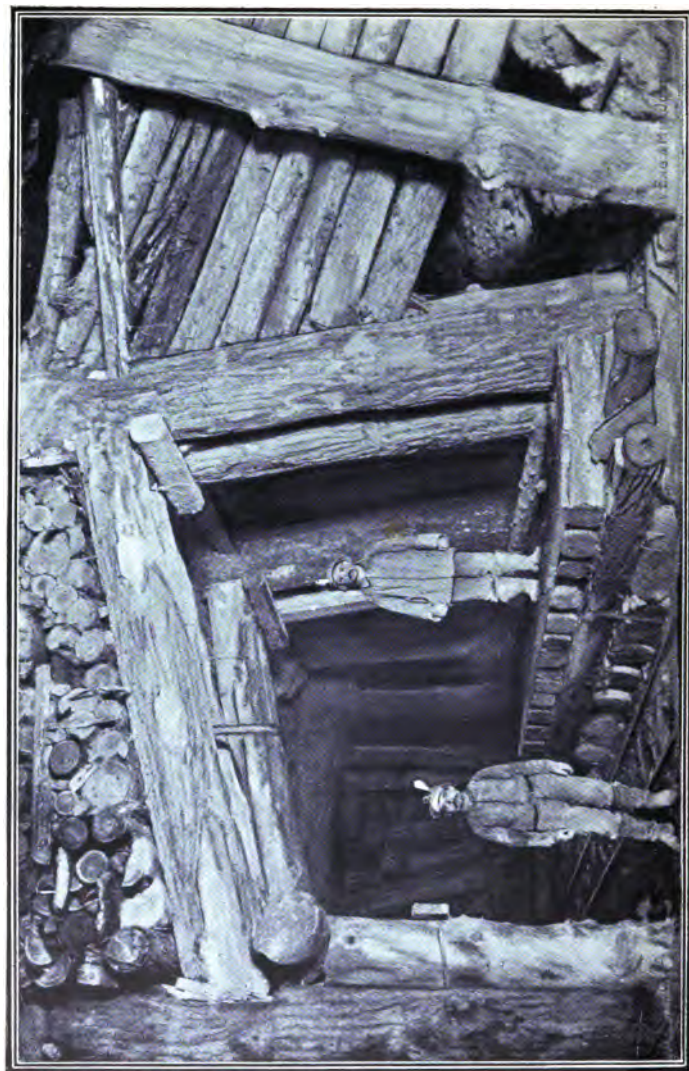


VIEW OF A COLLIERY GENERATING STATION

The plant consists of steam turbines driving three-phase, alternate current generators

PLATE I

To face page 16



EXAMPLE OF TIMBERING IN A METALLIFEROUS MINE

PLATE II

To see page 17

Introductory

deposits ; but it is now known that coal exists almost everywhere. South America is the last country to be explored for coal, and from the accounts recently received it is apparent that that rich continent is really not short of the most important of all minerals. From Spitzbergen in the North, to the neighbourhood of the South Pole, the great new continent which Antarctic explorers have discovered ; and from the Rocky Mountains on the West, round to Japan and China on the East ; in South Africa, in India, in Australia, in New Zealand, coal is found. Iron is also very largely found in nearly every country of the world. Iron very often occurs on the edge of the coal-field. It does so in the United Kingdom and in America and elsewhere, and mining engineers know, when either coal or iron is found under certain conditions, that the other is very possibly not far off.

Gold is found in nearly every part of the world also. The Rand gold mines in the Transvaal in South Africa are at present the largest producers, but it has been found for ages past almost in West Africa, and is now being mined there on a large scale ; it is found in the comparatively warm climates of California and Brazil, and again in the bitterly cold climate of the River Yukon in Western Canada and Alaska. It is found in India, in China, in different parts of Australia, and fresh deposits are constantly being discovered. Some of the other minerals are not so largely distributed. Copper is only found in certain parts of the world : in Spain and Portugal, on the borders of Lake Superior in America, and to a small extent in Cornwall and elsewhere. Tin has been mined in Cornwall for centuries, and is found in the Straits Settlements, in America, and to a small extent in Germany, and recently in Nigeria. Diamonds and rubies are only found in certain favoured districts, diamonds being principally confined to a small area in South Africa, while a small quantity are found in Brazil and elsewhere. Lead is found in certain districts, and is not very widely distributed.

Other minerals are alum, amber, asbestos, antimony, clay, cobalt, graphite, gypsum, manganese, nickel, nitrate of soda, oil shale, petroleum, potassium, phosphate of lime,

Mining

zinc. These occur in various forms, sometimes "native," sometimes in combination with other substances, in different parts of the earth. The methods of obtaining the principal minerals that will be described cover those of obtaining the less known and less abundant ores.

MINING BY THE ANCIENTS

Very little is known of the mining that was done by the ancients. It is pretty clear that mining of some kind must have been carried on, as the very earliest historical records give accounts of gold and silver ornaments, and of precious stones. Copper was known and employed for the making of tools before iron ; and iron itself has been mined for a number of centuries at least. Old workings are being found by explorers in different parts of the world, showing that mining of a sort was carried on in ancient times ; but it appears to have been carried on in a very crude manner, according to modern notions. One would describe it as merely scratching upon the surface. Slave labour of course was plentiful in ancient times, and slave life was not precious ; but even slaves could not perform the work that is done by the aid of machinery in extracting minerals from the great depths to which modern mines extend. However callous taskmasters might be, a slave could not work where he could not live, where he could not breathe, and though the art of ventilation appears to have been known to the pyramid builders in Egypt, there does not appear to be much evidence of its being applied in such mining as was carried on.

CHAPTER II

METALLIFEROUS MINING

GOLD, TIN, COPPER, AND LEAD MINES

THOUGH, as explained in the previous chapter, the minerals from which these different metals are extracted lie in different conditions, the method of mining them all is very much the same. Gold and tin mining resemble each other very closely ; in fact, Cornish tin miners have been in great request upon the Rand and in other gold-mining districts. As explained, the ore in which the gold and the tin are found usually lies in a fissure, extending from the surface of the ground downwards to depths the limits of which have not yet been reached. The fissures are usually inclined to the perpendicular, at a small angle ; the angle varying with different fissures, and in each fissure, as it proceeds downwards, as shown in Fig. 2. Nature has been very irregular in all the work she has done in producing minerals, and never more so than in the laying of the fissures and other receptacles in which metal-bearing ores are deposited. Fissures, or other cavities in which the ore is found, run along ridges,

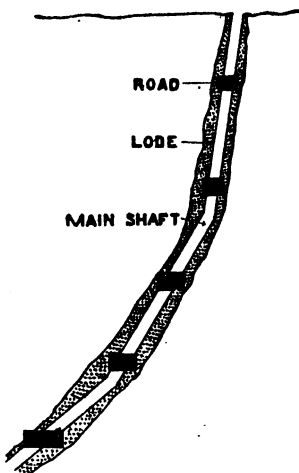


FIG. 3

Diagrammatic representation of an old-time shaft in a tin mine. The shaft follows the lode. The black masses are levels, or roads.

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often for a long distance ; one lode being recorded which runs along for a distance of 150 miles. On the Rand, the gold-bearing ridge, or reef, runs for several miles. In the early days of mining, and up till quite recently, the practice was to sink shafts in the lode itself, at the same inclination as the lode. The shafts, in fact, followed the lode. Fig. 3 is a diagrammatic representation of an old-time shaft. Modern practice is to sink vertical shafts, as shown in Fig. 4, at convenient points, and to drive what are called "levels," practically roads in the ground, at different depths below the surface, to meet the lode. In modern mining also, where, as on the Rand, it is known that the lode extends to great depths, vertical shafts are sunk to meet it at different depths, some at comparatively small depths, others at great depths. A shaft is merely a hole in the ground, sunk to whatever depth may be required for the extraction of the mineral. A well is a small

shaft ; and, on the other hand, a mine shaft may be looked upon as a large well. Mine shafts vary in size and in form. In Lancashire and Staffordshire, and in other parts of the United Kingdom, old mine shafts may be seen which look very much like rather large chimneys. They are circular in shape, and are merely erections carried a sufficient height above the abandoned holes in the ground

to prevent passers-by from falling down them. Those old shafts were very much smaller than modern mining shafts. The shafts of metalliferous mines are nearly always rectangular in form ; that is to

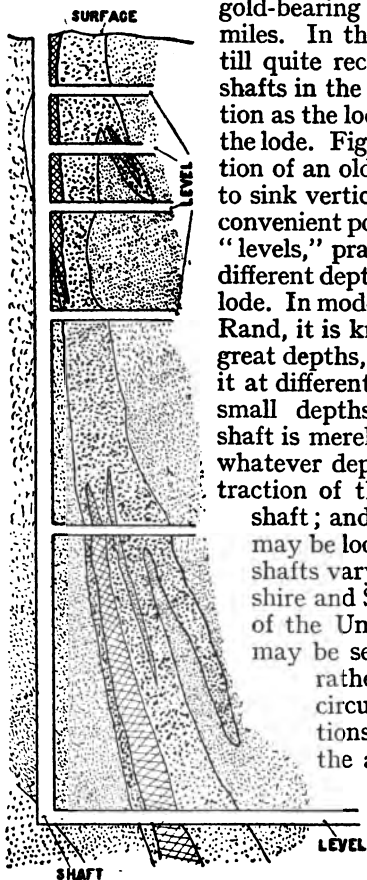


FIG. 4

Showing a vertical shaft with levels driven out to meet the lodes.

say, they are longer in one direction than in the other ; and they are divided by means of partitions, portions being

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reserved for raising the mineral ; other portions in modern mines are reserved for the pipes that are required to be taken into the mine ; and other portions again for hoisting men up and down, and for the ladders by which men can ascend and descend, if the hoisting machinery is out of order. In some of the older mines in Cornwall, at any rate, there was no hoisting machinery for men, everyone having to go up and down the shaft by the aid of ladders.

The mineral is often reached also by what are called "adits"; virtually tunnels or "day-light holes," running in from the side of a hill, to meet the lode, as shown in Fig. 5, very much in the same manner as explained in a previous chapter for working some of the shallower portions of coal seams.

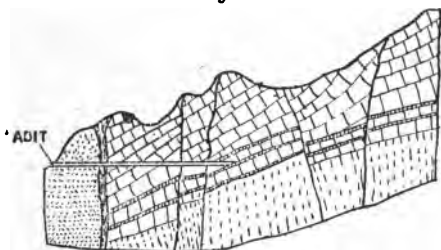


FIG. 5

Showing how a lode is reached by an adit.

In all cases, both gold and silver and copper and tin and lead mines are worked by the aid of shafts, either in the lodes themselves, or sunk perpendicularly in the ground in the neighbourhood of the lodes, together with "levels," or roads leading from the shafts into the lode itself. Where the shafts are sunk in the lode, the "levels" are simply driven out right and left at each level. Where the shafts are sunk perpendicularly, or as engineers express it, vertically, the levels are run from the shaft to the lode, and thence right and left in the lode. In all mining work the bulk of the underground haulage, the moving of the mineral itself, is done in roads and shafts formed out of the mineral

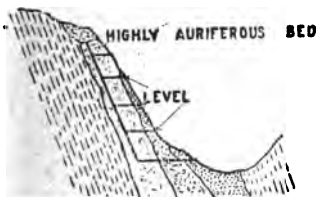


FIG. 5A

Diagram showing several adits or levels running into the side of a hill, where there is a rich lode.

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itself, the space occupied by the roads or shafts, where it is practicable, having been previously occupied by mineral. In Cornish mining circles there was considerable controversy for a long time, upon the relative advantages of sinking shafts in the lode and sinking vertical shafts near the lode; with the advance of modern thought in mining the vertical shaft has triumphed, and in all modern mines, on the Rand and elsewhere, the writer believes he is correct in saying that only vertical shafts are employed. Where, as in some copper mines, notably the Lake Superior and the Rio Tinto Mines, the extent of the lode is limited in length as well as in width, though not in depth, the same method of working is adopted; shafts are sunk at different parts of the lode, and levels are run out at different depths between the shafts. The depths to which the shafts are sunk vary in different districts, and with different mines. In metalliferous mining work depths are usually reckoned in fathoms, the fathom being 6 feet; and the levels are sometimes 10 fathoms apart, 10 fathoms below each other, sometimes at greater distances: 12 fathoms, 20 fathoms, and so on. The distances apart depend entirely upon the mineral that is to be worked, and the kind of work that has to be done in getting it out. As far as possible, the bulk of the ore, the bulk of the lode, is taken out between the shafts and between the levels. A portion of the lode is sometimes left, but this practice is only adopted in special cases where it cannot be avoided, and occasionally where the portion left is not of much value. The levels are kept open—to enable men to pass along them and the skips and wagons—very largely by the use of timber. As already explained, the lode is nearly always at a small inclination to the perpendicular, and therefore what is called the hanging wall, the upper side of the lode, the portion of the lode above the level, and sometimes what is called the foot wall, the enclosing wall on the opposite side of the hanging wall, require support. This is accomplished generally by the aid of timber. In South African mines teak is largely employed; in Australia the varieties of the eucalyptus known as the Jarrah and the Karri are employed; while in other countries the native timber is used as far as possible. In the

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United Kingdom oak is used where possible, but larch and fir are more largely employed. Larch and fir have the great advantage that they are straight and are easily adapted to the work required of them. Timbering a level requires a considerable amount of experience to know where the timbers should be placed, and a considerable amount of skill in fixing the timbers in their place, so that they will perform the work that is required of them, and that the strains, as engineers term it, the tendency to break the timber, shall be in the line of its length. Plate II is an example of timbering in a metalliferous mine. In some cases it is necessary to form a complete arch of timber to completely enclose a level. Such an arch and an invert is shown

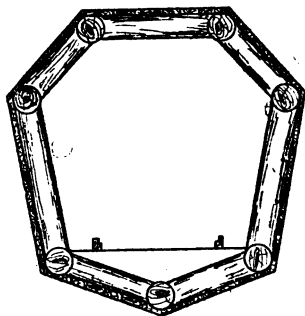


FIG. 6

Example of timbering to form a complete arch and what is called an "invert."

in Fig. 6. It will easily be understood that the cost of timber, and of the labour of fixing the timber, may form an important item in the expenses of working the mine. In metalliferous mines the timber is rarely recovered; in coal mines a good deal of it may be. Considerable judgment is necessary, therefore, on the one hand, not to use too little timber, and so endanger the working of that portion of the mine, and, on the other hand, not to use too much timber, and so increase the working expenses. In metalliferous mining, while in certain special cases very large dividends are paid, in a great many cases the margin between the cost of obtaining the mineral and preparing it for the market, and the price obtained for it, is not a large one. It is only by handling a very large quantity of the mineral, and by great care in winning and preparing it, that profit is obtained. In the case of certain mines, such as those working the Great Comstock silver lode, and those working the great copper lodes of Rio Tinto and Lake Superior, the uncertainty usually present in mining does

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not exist in the same degree ; but there is still some uncertainty as to the quality of the ore that will be produced from day to day. A little while back a disastrous fire occurred in a metalliferous mine in America, owing to some of the timber catching fire, and it was found necessary to

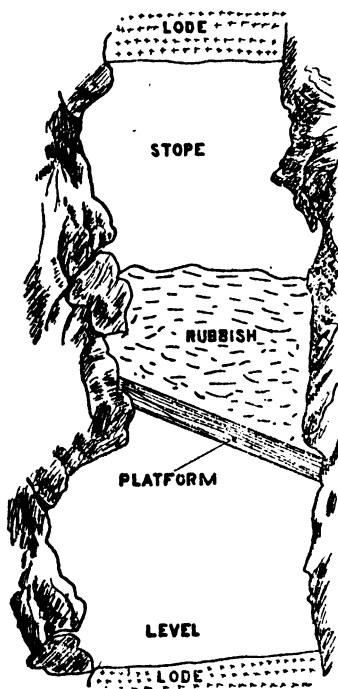


FIG. 7

Typical "stope" in a metalliferous mine.

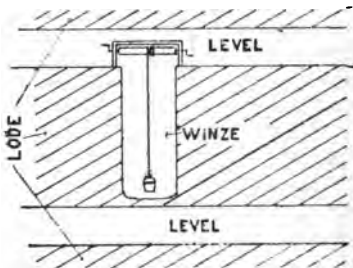


FIG. 8

Typical "winze" in metalliferous mine.

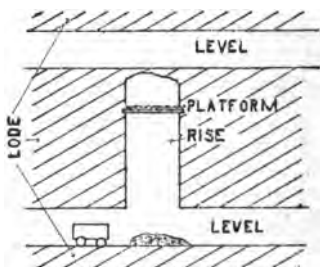


FIG. 9

Typical "rise" in metalliferous mine.

drawn the mine out before the fire could be quenched. It will be seen from this what a very large amount of timber had been used.

The ore between the levels and between the shafts is removed by the process known as "stopping," and by what are called "winzes" and "rises." A "stope" is virtually

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a cave in the mine, formed by the removal of a certain quantity of the ore from above the road over which the stope is formed. One kind of "stope" is shown in Fig. 7. A "winze," shown in Fig. 8, is a small perpendicular shaft carried down from a higher to a lower level; and a "rise," shown in Fig. 9, is a similar small shaft carried from a lower to a higher level. In the working of the mine and in the removal of the ore stoping and the formation of winzes and rises are constantly going on. Every winze that is cut means so much ore removed, and similarly every rise and every stope mean the same. Whether rises or winzes or stopes are employed depends entirely upon the condition of the ore itself and upon the enclosing rocks. The wall which lies above the ore, the boundary of the rock in which the original fissure was formed, is called the hanging wall; it corresponds to the roof of a road upon the level in a coal mine, and the other wall, the other boundary, is called the foot wall. Provision has to be made for supporting the hanging wall, all along each level, and in each rise and each winze.

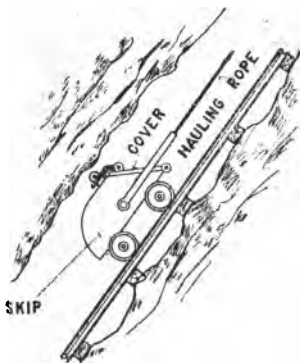


FIG. 10

Diagram showing "skip" in typical metalliferous mine, working in an inclined shaft.

In copper and other mines, where the ore lies in masses, much the same system of working by rises and winzes and stopes is carried on, and the ore is all got down on to the different levels. In all metalliferous mines the ore is removed along the different levels to the shafts, and is conveyed by the shafts to the surface, where it is dealt with as will be described later.

The fact that all the early shafts were sunk in the lode itself led to the adoption of a particular form of carrier, or cage, called the "skip," for hoisting the mineral. At the present time, even in some of the Rand mines, while the

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shafts are sunk to a certain depth perpendicularly, below those depths they are continued in the lode, and the "skip" is employed there. A "skip" is shown diagrammatically in Fig. 10. It is made to run in a horizontal position along the levels, upon rails provided for it, and then to run at the various inclinations at which the shaft is formed, as it is being hoisted. It is a rule, the writer believes, in Cornish mines that men are not to ride up and down in the skip, but he believes that the rule is often broken. He has heard eminent Cornish mining engineers talk of going down in the skip. Anyone who has ascended a Cornish mine by

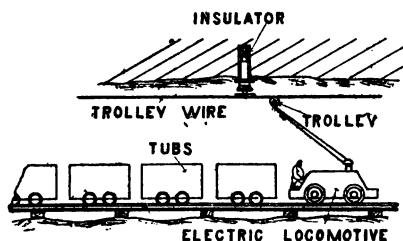


FIG. 11

Diagram showing an electric locomotive hauling a train of mine wagons along a level.

the aid of the ladders provided will not be surprised at anyone running the risk and discomfort involved in riding in the skip. In some of the old shafts the head of the skip, and consequently the head of a man riding in the skip, would at times be hanging downwards. The skips are pushed along the levels in the great majority of cases by hand. They are landed empty from the shafts at the different levels, are run along to where the ore is ready for them, are filled, and are run back to the shafts, where they are attached to the winding rope and hauled to the surface. Rope haulage has been introduced into modern metalliferous mines. In some gold mines on the Rand electric locos are employed for hauling wagons along the levels. Fig. 11 shows the arrangement. Wagons similar to those used in coal mines, known as "tubs," and shown in Fig. 11, are used in modern metalliferous mines, where the shafts are vertical.

HOW MEN GO UP AND DOWN METALLIFEROUS MINES

In modern mines, such as those on the Rand, in which

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the shafts are vertical, the cages carry the men up and down in a similar manner to the cages in coal mines. This applies also to some of the large skips, that are really cages, a good view of which is shown in Plate III, which is taken from a shaft on the Rand. In the older mines, however, the principal method of ascending and descending was by means of ladders, as shown in Fig. IIA. Platforms were arranged all the way down the mine, upon which the ladders stepped, and from which the next ladder descended. The author has gone down a mine 400 yards deep in Cornwall by ladders, and found the ascent very exhausting. In a few of the mines, particularly the deeper ones, such as the great Dolcoath Mine, what was called a man engine was employed, as shown in Fig. IIB. It consisted of two rods arranged to move up and down in the shaft. The rods were very much like those employed for working the buckets of the large mine pumps. It was so arranged that one rod was ascending while the other was descending.

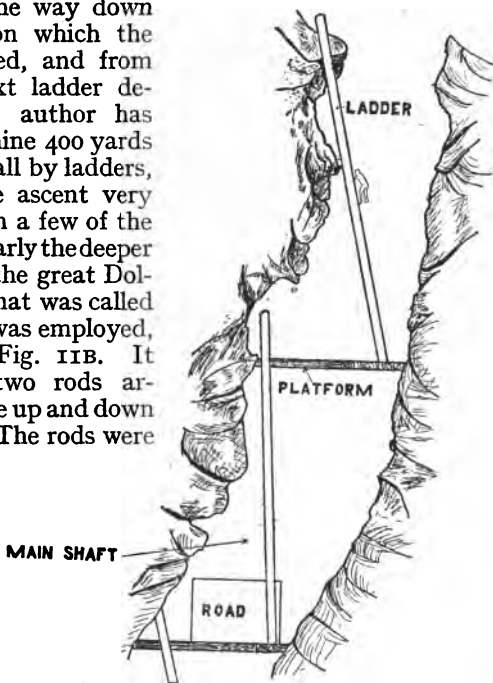


FIG. IIA

Showing method of ascending and descending the older metalliferous mines, by means of ladders.

Platforms were fixed at definite distances upon each of the rods, and when the rods were at rest, which was at the end of each stroke of the engine which moved them, two platforms, one attached to each rod, were opposite each

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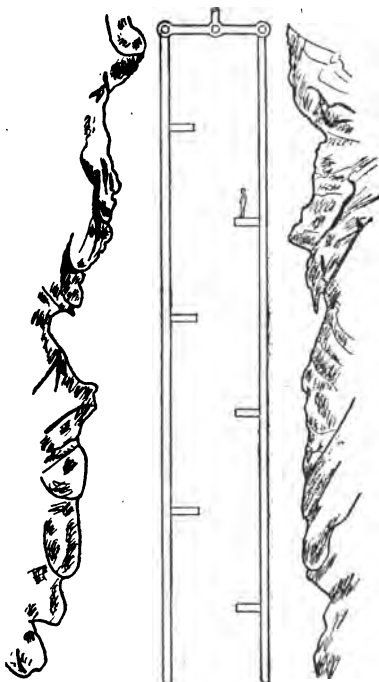


FIG. 11B

Showing the man engine employed in some of the Cornish mines. The two rods shown, one on each side of the shaft, rise and fall alternately. The platforms shown come opposite each other when the movement of the rods ceases, and the men step from one to the other; in that way being continually carried up or down.

ores. In some cases the metal itself is distributed, "native" as it is termed; that is to say, in fine grains of the actual metal among the particles of the stone in which it resides. In other cases it is combined with some other substance, and again the compound is held with non-metallic bodies, the whole forming the mass of ore-bearing rock. In all cases a very large quantity of rock, or stone, has to be detached from its bed, raised to the surface, and handled

other. To descend, a man stepped on to the top platform, and at the next stroke of the engine he was carried down a certain distance. He then stepped on to the platform of the other rod, which had been ascending during the previous stroke. This rod now descended and carried him another distance, and he again crossed over. To come up the opposite rule followed. He stepped always on to a platform attached to the ascending rod. Plates III and IIIA are views taken in shafts in South Africa.

HOW THE ORE-BEARING ROCK IS WON

In mining parlance, detaching the mineral from its bed is to "win it," sometimes to "get it." As explained in the previous chapter, all of the metals are found in the form of

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there in the manner to be described to produce a very small quantity of the metal. In the case of gold, a ton of rock has sometimes to be handled for the production of 3 dwts. of the metal; 20 dwts., or 1 oz., is considered a very good mining "proposition"; ore bearing as much as 2 and 3 oz. per ton is considered of very great value indeed.

The rocks in which all of the metals, whether held as compounds with other substances, or "native," are present, are nearly always hard. Tinstone, as it is called, is particularly hard, and so is the rock from which gold and most of the other ores are produced, and the masses of rock that are to be dealt with are broken away from the enclosing rocks by blasting. Holes are drilled in the rock to considerable depths—6 feet or more—gunpowder, dynamite, and various other explosives are placed in the shot hole, as it is termed, and the body of the hole not occupied by the charge is then filled with what is called "tamping," a substance that is not combustible, and whose office is to prevent the charge forcing it outwards. The object to be attained by the explosion of the charge is the breaking away of the rock that it is required to get down from the other rocks, and that is accomplished by the rending action produced by dynamite and other explosives; the rending action being distributed as far as possible in each direction, except in that of the shot hole itself. Drilling a shot hole, and charging it, requires a considerable amount of skill. Fig. 12 shows a shot hole with its charge of explosive, the tamping, and an old-fashioned fuse.

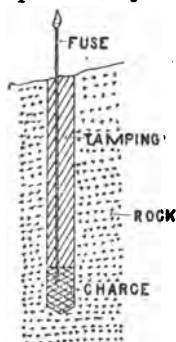


FIG. 12

Showing a shot hole, with its charge, the tamping, and an old-fashioned fuse.

HOW SHOT HOLES ARE DRILLED

Broadly there are two methods of drilling shot holes: by hand and by machine. Before the advent of machine drills, of course all holing was done by hand; and while machine drills are steadily displacing hand labour, there is

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still a considerable quantity of the work done by hand, because hand drilling is so much more flexible. With hand drilling two men are employed, one holding the drill, and the other wielding a sledge-hammer. They usually take turn and turn about at the two parts of the work. Various machines have been worked out to assist hand drilling, that is to say, to produce a better result with the same amount of labour, but it is the common experience that no machine is equal to two good men working turn and turn

about, and provided with good drills and good sledge-hammers. The drill is made of the very best steel, brought to a chisel point, and is turned round in the hole after each blow of the sledge.

The machine drill does the same thing, but by the aid of power applied by compressed air. Air is compressed on the surface of the mine; it is carried down the shaft in the pipe compartment in large pipes; smaller pipes are connected to the large pipes at each level, the small pipes being carried along the

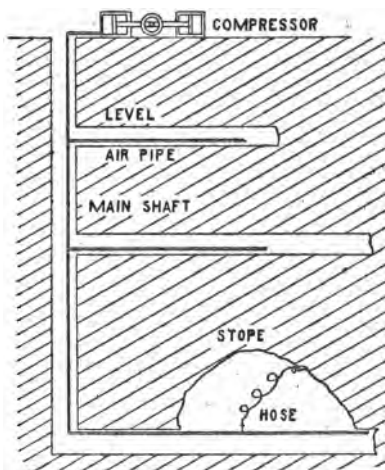


FIG. 13

Diagram showing the arrangement for delivering compressed air to the working places in the mine.

levels to the different working places, where they are connected to the machine drills either by hose or, in modern work, by flexible metallic tubing. Proper junction pieces are provided for connecting the small pipes to the large ones, and for connecting the flexible pipes to the fixed pipes. Fig. 13 shows the arrangement for distributing compressed air to the drills by pipes from the surface. Notwithstanding every care, however, there is a large amount of loss of power by leakage of air at the junctions,

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and often from cracks in the pipes themselves. A mine, it may be mentioned, is constantly "on the work," as it is termed; if left to itself the floor of a level rises, the roof or the floor of the level above comes down, and the sides or hanging and foot

walls come in, as shown in Fig. 14. The timbering referred to above prevents this, if it is properly carried out, but in spite of the greatest care in timbering there is a considerable motion of the rocks, and this leads to the bending and some-

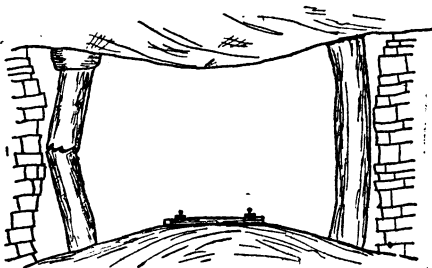


FIG. 14

Diagram showing how a roadway in a mine closes up, owing to the pressure of the overlying strata.

times to the cracking of pipes. Several attempts have been made to work machine drills by electricity, but so far without success. Compressed air is not only wasteful by reason of the leakage of the air; there are losses in the operations of compressing the air, in its flow through the pipes to the machines employing it, and its use in those machines. With the earlier forms of machine drills each drill was estimated to take about 3 horse-power to work it, and it was estimated that it was necessary to apply 15 horse-power to the compressor on the surface to furnish each 3 horse-power required by each drill. With the later forms of machine drills smaller powers are taken by the drills themselves, from 1 to $1\frac{1}{2}$ and occasionally 2 horse-power, while the power required by the compressor on the surface for each drill is in the neighbourhood of from 5 to 8 horse-power.

By horse-power, engineers mean the rate at which work is being done. One horse-power is supposed to be the work which one horse could perform continuously. When steam was being introduced more than a century ago James Watt, the Father of the Steam Engine, estimated as carefully as possible, from actual observation, the work the horse could

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do. It is now known that he was very liberal in his estimate, and that there are few horses that could perform the work he credited them with. The work of 1 horse-power, however, is approximately the lifting of 16 tons 1 foot from the ground, in one minute, or 8 tons 2 feet from the ground, 4 tons 4 feet from the ground, and so on, all in one minute. When work is required to be done continuously the number of horse-power hours is reckoned; that is to say, the number of horses' power required and the number of hours for which they are required, and the engineer who is designing the plant provides machinery that will furnish power at that rate, after allowing for all losses.

THE MACHINE DRILL

Two forms of machine drills are shown in Plates IV and IVA. The drill shown in Plate IV is known as the piston drill; it is virtually a small engine, similar to those worked by steam, but in this case worked by compressed air, the drill being attached to the piston itself, or to a rod mechanically attached to the piston. Compressed air is admitted behind the piston, and forces it forward by reason of the pressure that has been given to the air on the surface. In the process of moving forwards the drill strikes the rock in front of it and chips it away, very much in the same manner as the hand drill does when struck by the sledge-hammer. After the piston has reached the end of its stroke, which will be when the drill has struck the rock in front of it, the compressed air enters the machine in front of the piston and forces the drill backwards, slightly turning it in the process, just as the man who holds the drill does with hand drilling. As will be seen, the machine is arranged to be fixed in any position between the roof and floor, and the drill follows the hole as it becomes deeper and deeper, longer and longer drills being fixed in position as each one comes to the end of its length. In the later form of machine drill, which is known as the "Hammer Drill," a considerable amount of power is saved, and the action is brought very much nearer to that of the sledge wielded in hand holing. The drill moves in and out in front of the machine as in the piston drill, but



VIEW OF A CAGE OR SKIP TAKEN AT ONE OF THE LEVELS IN A MINE SHAFT ON THE RAND
The skip has been stopped at the No. 8 Level for some of the miners to get out.
 PLATE III



VIEW IN THE SHAFT OF ONE OF THE MINES ON THE RAND
 TAKEN FROM THE MOUTH OF ONE OF THE LEVELS
 PLATE III A To face page 32

(The above photographs are reproduced from "South African Engineering" by permission of the Editor.)



PLATE IV A

HAMMER DRILL

To face page 33

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it is not attached to the piston. The piston carries what is virtually a hammer, which strikes the drill. The drill is brought back and turned by mechanism arranged for the purpose, but it does not come back the whole of the distance, as in the piston drill, and so considerable power is saved; and in addition the whole thing is very much lighter, and more portable. For drilling into softer rocks rotary drills are employed, the tool itself being shaped like an angle, and working its way into the rock in the same manner. Plate IVA shows the hammer drill.

THE ELECTRIC AIR DRILL

Plate V shows the electric air drill, which is claimed to combine the advantages of electricity and compressed air. Electricity is very much more economical for transmitting power than compressed air; but as explained above, it has not yet been employed to work the drill directly. In the electric air drill a small compressor is attached to each drill, as shown in the plate, and the compressor is driven by a small electric motor. The air which is compressed is taken by means of a flexible pipe to the drill, and after performing its work upon the piston is brought back to the compressor, where it is re-compressed, passes out again to do its work upon the drill, and so on. Other advantages are obtained by what is called the Closed Air Circuit, which there is not space to enter into here.

THE PROBLEM OF THE DUST FROM THE DRILLS

The great curse of the working miner is the complaint known as miners' phthisis. It is produced by the dust formed from the rocks in the process of drilling, which is inhaled by the miner, and which passes into his lungs. In addition, he also inhales the fumes from the explosives that are employed for blasting, and in some of the older metalliferous mines, at any rate, the ventilation was practically non-existent. Up till very recently there had been no attempt to introduce really efficient ventilation into metalliferous mines. There has been no law compelling the owners of metalliferous mines to provide a certain minimum cur-

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rent of air through their working places, as there has been with coal mines. There is no danger of explosions in metalliferous mines, leading to the loss of several hundred lives at once, as there is with coal mines ; and hence the problem of ventilation has never been seriously tackled until quite recently. With the greater depths at which minerals are being worked, and with the great heat which is present there, and perhaps still more from the awakening which has taken place in Governments all over the world as to their duties to workmen, and to the owners and managers of mines having discovered that men do better work, produce more mineral when at work under healthy conditions than the reverse, efforts are now being made to ventilate metalliferous mines to something approaching the condition of coal mines. In some forms of rock drill the drilling tool is hollow, and a stream of water passes through it into the shot hole, carrying the dust out with it, and depositing it on the ground.

THE HEAT IN DEEP MINES

One of the difficult problems that arise in connection with metalliferous mines, when the levels approach to great depths, is the high temperatures that are met with. There appears to be great uncertainty as to the actual proportion between the depth and the increase of temperature, but it is perfectly clear that there is a rise of temperature as the depth increases. In some cases it has been found to be as much as 1° of Fahrenheit's thermometer, the thermometer used in private houses, greenhouses, etc. for every 50 feet of depth ; in other cases it has been found that 60 feet, 70 feet, and even greater depths have been required to produce 1° F. increased temperature. In the Yellow Jacket Mine of the Comstock lode in the State of Nevada, America, at a depth of 2700 feet, the temperature of the air was found to be 126° F., and that of the water 153° F. ; while at a depth of 3065 feet the temperature of the water was 170° F. As will be explained later, these high temperatures in the water met with in mines create an additional difficulty in working them.

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HOW THE BLASTS ARE FIRED

Up till very recently, and even now in a very great many mines and in a great many districts, the charges, whether of gunpowder, dynamite, or one of the other powerful explosives, are fired by what is called the "miner's squib," consisting of a straw with some damp powder in it, the straw being inserted in the charge and the other end coming out of the entrance of the shot hole, as shown in Fig. 12. The miner lights the outer end of the squib, and, it being damp, the time it takes to reach the charge enables him to get out of the way. In a later method, what is called a safety fuse is employed. This is very much the same, but the fuse is made up in a proper form, usually in a long length, and consists of a gutta-percha tube, carrying a special composition on the inside which burns at a known rate. A certain length of the safety fuse is cut off from the coil or reel, one end is inserted in the charge, the other end being on the outside of the shot hole, and, in the same way as with the squib, the time occupied by the composition in burning its way through to the charge enables the miner to get out of the way.

All of these methods, however, are giving way to electrical ignition. An electric fuse is shown in Fig. 15. It consists of two copper wires insulated by gutta-percha or india-rubber, the outer ends being embedded in a detonating substance, such as fulminate of mercury, and the inner ends being attached to insulated wires for the purpose of making connection to the source of current. Electric fuses are known as "high tension" and "low tension." In the high-tension fuses the fulminate of mercury is ignited by a spark which passes between the ends of the copper wires; in the low-tension fuses there is a fine platinum wire bridge between the two copper wires, and a current of electricity passes through this at the moment of firing, heating it up and

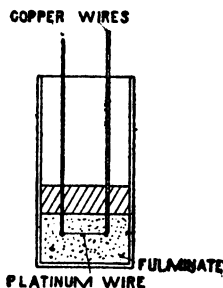


FIG. 15

Diagrammatic section
low-tension electric fuse
employed in firing shots
in mines.

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igniting the fulminate. A low-tension fuse is shown in Fig. 15. The fuse with the fulminate of mercury, which is protected by a copper cap, is inserted in the charge, and the connecting wires are led to the outside of the shot hole, where they are connected to a firing battery, which is a small magneto-electrical machine in the case of high-tension fuses, and may be the same or a battery of galvanic cells in the case of low-tension fuses.

Firing by electricity has the advantage that several shots can be fired at the same time, so that the breaking-down action of several charges of dynamite can be brought to bear at the same time. It is also claimed that while with the squib, or with the safety fuse, the miner must not go near the shot hole for several hours after he has ignited it, if it does not immediately fire the charge, with electrical ignition he can return immediately if the charge has apparently not fired. There have been, however, cases recently of accidents occurring from unfired electrical fuses, and therefore while electric firing is certainly much more convenient, and much safer, it is not so absolutely safe as it has been claimed.

CHAPTER III

METALLIFEROUS MINE SHAFTS

AS explained above, mine shafts are really holes dug out of the ground, and it is necessary in order that the mineral shall be raised through them, and that men shall go up and down them, that the holes shall be kept open, and that their size and form shall be maintained always the same, or as nearly so as possible. The shafts, therefore, are always lined with something. Modern shafts are lined with either brick, concrete, stone, or, as is becoming more frequent, metal. The earlier shafts were lined with wood; and again in the very early days, when the mine shafts were small, the methods of protecting the shaft itself were often very crude. Broadly, in the wood-lined shaft there are what are practically box frames, set at intervals in the shaft, one below the other. The box frames consist of two timbers running the width of the shaft, joined by two timbers across the end, a second set of pairs of timbers being fixed below the first, and supporting the first by pieces inclined to the perpendicular, in the line of the shaft. By a series of these frames the shaft is kept fairly clear, provided there is not much pressure and provided the shaft is not very deep. Further support is obtained by making ledges in the rocks bounding the shaft, at intervals, and supporting the cross pieces of the frames described above in them. It will be seen by this arrangement each set of frames, above each of these special supporting timbers, is supported directly by the rock itself. Some of the modern mines on the Rand are constructed on something the same lines, but the whole thing is very much stronger than in the case of the early mines. The timbers are very much thicker, the supports in the rocks very much more

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frequent ; the timbers themselves have been subject to one of the processes for preserving their life before being used, and so on. Fig. 16 shows the arrangement of a modern mine shaft in which timber is employed, and how it is divided up for the different purposes. The figure, which is known as a plan, which shows the timbers as they would be seen when looking straight down upon them, is taken from a shaft on the Comstock lode. It will be seen there are three hoisting compartments and one pumping compartment. In some modern mines there are as many as seven compartments. In the Rand mines there are sometimes

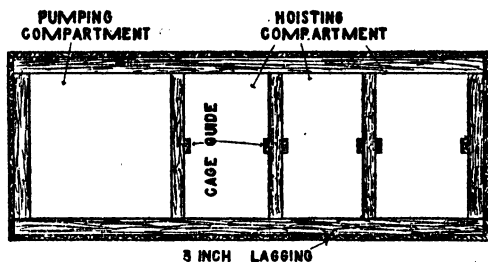


FIG. 16

Diagram showing the arrangement of a modern metalliferous mine shaft, with four compartments.

three compartments and sometimes more, and it is usual to reserve one compartment for men travelling.

Masonry—bricks, stone, and concrete—also ironwork are employed for the lining of modern shafts. Bricks made of the waste material that is sometimes brought out of the mine are employed ; stones that are found in the neighbourhood, or in the mine, where they are available, and concrete. Ironwork is not often used except with circular mines. Brick and stone and concrete and ironwork make very much more permanent structures than woodwork, and require considerably less repairs. The objection to their use is the greater initial expense. In the case of metalliferous mines it is often not known, when the mine is first started, how long paying ore will continue to be produced, and therefore not more expense than is absolutely necessary is incurred.

Metalliferous Mine Shafts

Where the ore has been proved and it is known that it may be depended upon to great depths, and always in paying quantities, more permanent shafts are provided.

These remarks apply also to the case of levels. Masonry—brick, stone, and concrete—is being employed more and more in the place of timber. Again, it is a case of providing permanent structures as against temporary. The timber and the masonry that are employed in levels have to support the weight of the overlying strata, and in many cases it will pay to provide masonry, especially in the deeper levels.

Steel is also gradually being introduced for the same purpose in the form of girders, and occasionally for both

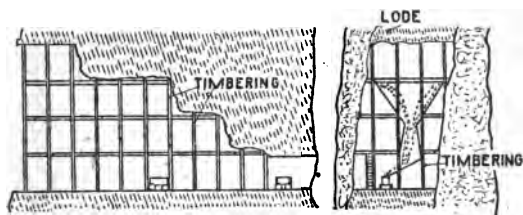


FIG. 17

Showing methods of timbering metalliferous mines.

girders and side supports. Fig. 17 shows some of the methods of timbering in metalliferous mines.

DIAMOND AND OTHER METALLIFEROUS MINES

As explained above, practically all the metal mines, quarries, salt mines, and a few others that will be detailed, are worked on the same lines as both tin and gold mines, though the ore occurs in very different forms.

Diamond mines are only found in South Africa to any great extent, though there are a few diamonds obtained from Brazil, India, and other parts. The principal diamond mines are situated in Cape Colony and the Orange River Colony. The deposits in which they occur are virtually enormous pipes or shafts, supposed to be the craters of extinct volcanoes, into which large quantities of the "blue ground" or mud, in which the diamonds are found, have

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been forced by later volcanic action from below. The large diamond mines in South Africa were worked for a considerable time as open quarries, but as the work proceeded it was found necessary to sink shafts and to drive out levels, very much as in the gold and tin mines. The diamonds occur in the form of pebble-like stones embedded in the "blue mud," and a large quantity of the mud has to be handled in order to obtain a comparatively small quantity of the diamonds. In handling the "blue ground" from which the diamonds are taken, each load of 16 cubic feet returns only from $\frac{1}{4}$ of a carat to $1\frac{1}{2}$ carats. Very large diamonds are found occasionally, and they are known largely by their great weight; but a very considerable proportion of them are small.

SULPHUR MINING

Sulphur occurs principally in the neighbourhood of volcanoes. It is found in Iceland, and also to a small extent in connection with quicksilver mines; but the principal

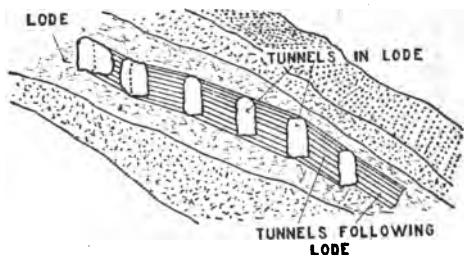


FIG. 18

Diagram showing method of working sulphur mines.

sources of production are in Sicily, and other parts of Italy. The sulphur deposits lie in beds, very much like the coal seams, but they are worked in a somewhat different manner. Inclines are run into the deposit, in the line of the lode itself, of the dip as it is called, and from these inclines levels or tunnels are run out in both directions, at different distances below the surface, into the deposit itself. This

Metalliferous Mine Shafts

arrangement, it will be seen, corresponds to the shafts and levels, etc. of tin and gold mines. The principal difference in the working of sulphur mines is, after the levels have been driven out over a certain area they are abandoned, and the overlying strata, which is also sulphur, is allowed to come down, and the levels are again driven out through the debris, a fresh lot being obtained. The deposits of sulphur are sometimes as much as 164 feet in thickness, while beds of 20 feet thick are quite common, so that it will be seen that the arrangement for working on the above lines is perfectly practicable. Working in sulphur mines, it will easily be understood, is very unhealthy, and the great object to be attained is to get out as much of the material as possible with as little injury to life and health as possible. Fig. 18 shows the method of working diagrammatically.

SALT MINES

Salt mines are sometimes worked by the usual mining methods, shafts being sunk and levels driven out, leaving pillars of the salt between to support the roof. Large chambers are cut out of the deposit, the rock salt, and conveyed to the surface by way of the shafts, the pillars supporting the overlying strata forming the boundaries of the chambers.

Another method of working salt mines is as follows: A small shaft or bore is sunk into the bed of rock salt, and is lined with a tube. The rock salt lies under, in some cases at any rate, water-bearing sandstone. Sandstone and gravel, it may be mentioned, are the great sources of water, from which springs are obtained when wells are sunk to them. They are like sponges, which hold the water that runs into them at their "outcrops" at the surface, the water running down by gravity to the lower portions. The pipe which passes down into the rock salt is perforated where it enters the salt, and where it passes through the water-bearing strata. An inner pipe is fixed inside the bore-hole pipe, with a pump arranged to suck up from the rock salt. When the pump is worked water passes down from the sandstone through the outer pipe into the rock

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salt, and it there dissolves some of the salt, which is pumped to the top through the inner tube. In some cases the two methods are combined.

PETROLEUM AND NATURAL GAS

In the United States of America, and in other parts, natural gas, very similar to that which we burn in our houses, occurs in certain districts, and is mined ; that is to say, it is either allowed to force its way to the surface, or is pumped up to the surface, the result being as truly mining as any of the other processes. Petroleum, from which petrol, paraffin oils that are burnt in lamps, lubricating oils that are used for machinery, paraffin wax, and the substances now consumed in the Diesel engine are obtained, also occurs under very much the same conditions as natural gas. Both occur in porous strata, such as sand or gravel, and it is necessary that the porous strata carrying the gas or the petroleum shall lie on top of some strata such as clay, which prevents its passage through it. It seems to be also necessary that there shall be an overlying strata preventing it from getting away. When bore holes are put down into the porous strata, the gas and the petroleum sometimes come right up the hole without pumping, and sometimes have to be pumped.

SLATE AND STONE QUARRIES

It is usual to call what are really mines in which slate and stone is worked—quarries, though in many cases both slate and stone are obtained by underground workings. The open quarry may be seen on almost any country-side for stone working. The method of "open working" is employed not only for stone and slate, but for iron and coal and other minerals, whenever the mineral lies very close to the surface. In many cases the "outcrop" of a bed of mineral, even of coal, is worked by quarrying at the surface. It will be remembered that the "outcrop" is where the bed of mineral emerges at the surface, the bed usually descending into the earth's crust at a certain angle, so that it is found at greater and greater depths as the "out-

Metalliferous Mine Shafts

crop " is receded from. Stone is largely worked on the outcrop, though a considerable quantity is also worked by mining, or, as perhaps it might be termed, tunnelling. In opening out a quarry, or open work mine, it is necessary first to remove the soil; and in many cases, particularly where the extent of the workings is large, the soil is replaced, after the mineral has been removed, but of course at a lower depth, and cultivation proceeds as before. Besides the overlying soil in which cultivation takes place, there are often other strata between the surface and the mineral that is to be worked, and these are removed by successive steps until the mineral is reached. When the mineral itself is reached it is broken up by the pick, by blasting where necessary, and by other methods, loaded into wagons of various sizes, and hauled away in the usual manner. In some cases, with very large quarries, a very large amount of rock is brought down by a single blast, the rock after it is brought down being loaded into wagons and hauled away. With this method tunnels or levels are driven into the rock, and sometimes a short piece of tunnel or level is driven at right angles to the main tunnel. A very large charge of explosive is placed in a chamber at the end of this tunnel, and the whole of the tunnel between the explosive and the mouth is filled up, very much in the same manner as a shot hole is, with what would be called "tamping," stuff that will resist the force of the blast outwards. Turning the tunnel at right angles at the end of the main tunnel, it will be seen, assists the explosive to exert its full force upon breaking down the rock. In addition, tunnels worked for this purpose are sometimes made sinuous, irregular, so as to increase the resistance of the "tamping" to the force of the explosion. In one case 100,000 cubic yards of rock are stated to have been brought down in this way in a limestone quarry in Sicily, the length of the main tunnel or level being 56 feet. By this method the rock is brought down in larger masses, and there is a small quantity of small stone that is of course largely waste.

The great slate quarries of North Wales, and the smaller slate quarries of Cornwall, are worked partly upon the "open" system and partly as mines. At Festiniog, in

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North Wales, where there are so many large slate quarries, and where the veins of slate are as much as 70 feet in thickness, the working is very similar to tin and gold mines. The veins of slate, which are really beds, lie at a comparatively small angle with the horizontal, while the tin and gold veins lie usually at a small angle with the perpendicular. What correspond to shafts in gold and tin mines are run into the slate vein, at certain distances. Perhaps they correspond more nearly to the levels or drifts, or inclines, or daylight holes, by which coal seams are reached, when they lie near the surface. Fig. 19 shows the arrangement. Chambers, as they are called, virtually shafts, or drifts, or

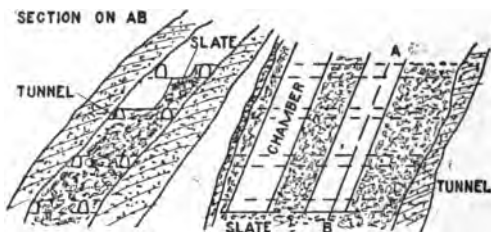


FIG. 19

Diagram showing the method of working large slate quarries in North Wales.

inclines, are run into the slate at intervals of from 30 feet to 50 feet, as shown in the figure. The unworked slate between the chambers or inclines forms pillars for the support of the roof. The inclines are worked by successive steps, as shown in the figure, and follow the vein down; what are called in Cornish mining, "rises," are carried up from each incline at different depths below the surface, and the whole of the slate is removed as far as practicable from the underlying strata to the overlying strata. In stone quarries, whether they are worked in the open, or by levels running underground, not much blasting is employed. The stone, though it often lies in great thickness, is easily detached from its bed. The mine is opened by levels, and by other levels at right angles, or in various directions, known as "side holes," the roads and side holes usually

Metalliferous Mine Shafts

being very wide, and the stone is removed by a simple though somewhat laborious process. A horizontal groove is cut in the top of the bed for a depth of 5 feet and for a width of 20 feet to 25 feet. Two vertical cuts are then made in the middle of the portion of the rock that is being worked, and the piece included between them is removed. After this, the remainder of the rock is easily removed by sawing and wedging. It is hoisted on to portable trucks by the aid of hand cranes fixed conveniently to the working places, and hauled out to the surface by the aid of horses. Plate VA is a view of a large limestone quarry in Colorado.

IRON MINES

Iron is found in nearly every part of the world, but the principal deposits in work at the present time are at Bilbao in Northern Spain, in Cumberland and North Lancashire and North Yorkshire in the United Kingdom, and in German and French Lorraine and Luxembourg on the Continent. Quantities of iron ore are also being constantly discovered in all parts of North and South America. Quite recently a very rich deposit has been discovered in Brazil, which will probably be worked by the "open" method, by quarrying. The iron is never found "native"; that is to say, it is always found in combination with some other substance, usually with oxygen, as one of the oxides of iron. The quantity of the metal obtainable from the ore in which it lies ranges from 25 per cent upwards. At the hematite iron mines in Cumberland one may see specimens of kidney ore, which is almost pure iron, and which contains from 90 per cent upwards; percentages of from 30 per cent to 50 per cent, however, are far more common, 50 per cent being considered good. The newly discovered deposits in Brazil are stated to contain 70 per cent of iron. The iron itself is found

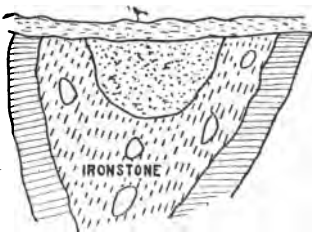


FIG. 20

Typical ironstone deposit in cavern formed out of limestone deposit.

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under very various conditions ; a large quantity of it, however, is found in what are practically limestone caverns, as shown in Fig. 20. Iron in a molten condition, and combined with other substances, has apparently been injected into the limestone, and has displaced some of it. In Northamptonshire and Lincolnshire it is worked by the open quarry method. In Cumberland and North Lancashire it is worked by a modification of the methods described for tin and gold mines. Shafts are sunk, usually perpendicular, either into the bed of the ore itself or into the strata close to it. From the shafts, levels are run out into and in the mass of the ore, cross levels being carried out from the main levels, and the whole of the ore being got out by very similar methods to that employed in tin and gold mining.

It will be understood that metalliferous mining is very similar for different kinds of metals ; where variations rule, it is owing to the difference in which the ore bodies lie. Where, as in the case of tin and gold, the lode goes downwards at a more or less definite angle, and lies in the fissure described, the ore is got out by working right and left from the shafts, where they are in the lode, and right and left from the levels which are carried into them from vertical shafts. Where, as with iron and other metals, the ore lies in masses—and all minerals are sometimes found in that form—either shafts or inclines are carried to the neighbourhood of the ore, and then roads are run into the ore, and right and left and at various angles, up and down as may be necessary, to extract the whole of it.

HYDRAULIC MINING

A method of extracting mineral from surrounding substances that is very popular, because it demands a comparatively small outlay, and which has been described to a considerable extent in novels where mining of the West has been referred to, had perhaps better be described. Gold is one of the minerals that are obtained by hydraulic mining. It is sometimes contained in what is called auriferous gravel ; that is to say, gravel containing quantities of gold

Metalliferous Mine Shafts

deposited among its mass. The gold is usually more or less "native"; that is to say, the grains of gold are separate, though adhering closely to the particles of the gravel, etc.; and if a sufficiently powerful force of water, applied in a proper manner, can be used, the gold is got away from the gravel. In one form of this method, known as "booming," and practised in the Western States of North America, large reservoirs of water are arranged at a height above the beds of auriferous gravel, by damming up streams for the purpose, and when a sufficient quantity of the water is stored a sluice is opened, and the whole body of the water is discharged violently over the gravel. The stream is supposed to carry away the stones and dirt in wooden troughs provided for them, leaving the gold behind on the bed rock and on the upper part of the sluices.

A more scientific method of dealing with the auriferous gravel is to play a powerful jet of water upon it, as shown in Plate VI. The gold-bearing gravel is displaced from its bed by the stream of water, and directed into a long line of wooden troughs, as shown in Plate VIA, arranged to catch the gold by the aid of mercury. The floors of the troughs are built up of wood and stones in such a manner as to catch the particles of gold, the mercury which is to catch them forming a lining to the bottom of the trough. The mercury, with the gold it has entrapped, is collected, washed, and subjected to heat, the mercury being driven off and the gold remaining, the mercury being recovered and used over again. What is called a "grizzly" is fixed across the main slope, to stop the large stones and rocks from passing into the troughs. The "grizzly" consists of a grating formed of iron bars; it allows the smaller gravel with its gold to pass through, but stops the passage of large stones and rocks, and they are usually directed off to some place out of the way.

USES OF HYDRAULIC MINING FOR OTHER MINERALS

Other minerals besides gold are obtained by hydraulic mining, the most striking instance being that of the china clay which is mined in Cornwall. China clay is believed to

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be formed by the decomposition of granite. There are not many deposits of it in the world. It is that beautiful white substance from which porcelain and china are made. A shaft is sunk into the deposit and water is run down, dissolving the china clay out. The solution of clay is run into a settling tank at the bottom of another shaft, to allow the other substances to separate out from it; and the china clay proper is then pumped up to the surface, where it is run into settling pits, and subject to other processes.

NITRATE OF SODA MINES

Nitrate of soda is the substance that is so valuable as a manure. A few years ago professors were calling attention to the fact that the nitrate mines in Chili and Peru were being worked out, and the result has been that substances furnishing nitrogen are now being manufactured on a large scale by trapping the nitrogen of the atmosphere; and also gasworks, and collieries where coke ovens form part of the plant, are manufacturing large quantities of sulphate of ammonia, which contains nitrogen, so that the nitrogen famine bids fair to be dealt with. The nitrate of soda occurs in beds up to as much as 12 feet thick, at a small depth below the ground. It is mined in a very peculiar way. A small shaft is sunk, practically a well, into the deposit, and a chamber is made at the bottom of the shaft. A charge of slow-burning powder is placed in the chamber at the bottom of the shaft, and is fired from above. The explosion breaks up the overlying ground and the deposit of nitrate, the overlying strata being then easily removed and the deposit brought to the surface and carried to the works in the neighbourhood for preparation.

POTASSIUM SALTS

The salts of potassium are also used as manure, and they are found as beds in different parts of the world, notably on the continent of Europe. They are worked by the aid of perpendicular shafts from the surface, levels being driven from the shafts into the ore, which is drawn along the levels to the shaft and raised to the surface.



ELECTRIC AIR DRILL WORKING IN A JAPANESE MINE
PLATE V



LIMESTONE QUARRIES IN COLORADO

PLATE V A

To face page 48



HYDRAULIC MINING BY THE AID OF A POWERFUL JET OF WATER
PLATE VI



HYDRAULIC MINING IN COLORADO
Showing the line of wooden troughs employed to catch the gold

PLATE VIA

Metalliferous Mine Shafts

RUBIES

Rubies are mined in Burma principally, in very much the same manner as described for other minerals.

DREDGING FOR MINERALS

Gold and other minerals are often deposited in the beds of rivers, and in these cases dredging has to be resorted to. Dredging is the process by which the beds of rivers and channels leading to shipping ports are excavated, so as to preserve a certain depth of water in them. The dredge consists practically of a very strong bucket conveyor, the endless chain with its buckets being supported at the upper end from uprights fixed upon a barge or raft, and at the lower end by a jib that can be placed at any angle with the horizontal that may be desired, according to the depth of the river bed. The barge or raft is usually housed in, as shown in Plate VIII, and carries an engine of sufficient power to transport the dredge and to work the endless chain of the elevator. The jib is lowered to the bed of the river, or wherever dredging is to be carried on, and the endless chain set in motion. The buckets, as will be seen from the drawings, are arranged to scoop up the mud and other matter from the river bottom, and to bring it up to the top of the elevator, where each bucket tips its load into a bin provided for it.

Modern dredges are used to cut their way into mineral-bearing flats on the banks of rivers. The elevator which brings up the deposit from the bottom sometimes delivers it to a conveyor that transports the ore to a bin as shown. Dredging is also sometimes accomplished by suction, the loose material at the bottom of the river being drawn up, just as water and sand are, and delivered to bins. Grabs are also sometimes employed, similar to those used for unloading coal barges in the Thames.

CHAPTER IV

TROUBLES IN MINES

WATER IN MINES

THE great majority of mines, and particularly metalliferous mines, are troubled with water. The rain which falls in such large quantities in pretty well every part of the United Kingdom sinks into the ground, gradually percolates through the different strata, and finds its way into any excavations, such as mine workings, beneath the surface. In addition, what are known as water-bearing strata—sands and gravels—from which our supplies of well water are obtained, often lie in close contact with mineral strata. In metalliferous mines, at any rate, there is usually a fairly continuous stream of water running down the shaft, and sometimes running over parts of the workings. The workings may tap reservoirs of water, and again where they run under the sea, as in the case of some Cornish mines, they occasionally let in sea water. In all mining, at any rate, the water that is present is nearly always a cause of trouble, and an expense; it has been aptly termed a "profit sharer." In some metalliferous mines so great is the quantity of water that when they are not working the water rises in the shafts to a considerable height. During the Transvaal war, when all the gold mines on the Rand were stopped, the water rose quite half-way up some of the deep shafts, and in some cases to greater heights. Water obeys the well-known law in this case, viz. it finds its own level. The water-bearing strata outcrops to the surface, and the pressure of the water carried in its pores forces any body of water, such as that in a mine shaft, up to its own level. The mine shaft is virtually a well.

Troubles in Mines

One of the troubles in connection with water found in metalliferous mines is, it nearly always contains salts in solution, and therefore, though a considerable amount of power has to be expended in pumping it out of the mine, the water itself is generally useless when it reaches the surface. In Cornish mines it is sometimes made use of to furnish power for driving some of the machinery, where the mine is on the top of a hill, and it is also used for washing the tinstone, and is allowed to run down to the river, the tin which it carries away being trapped at successive points. "Tin streams," as they are called in Cornwall, are often valuable propositions.

HOW THE WATER IS GOT RID OF

There are two methods of getting rid of the water: one is by draining it out through an "adit," where that can be done, and the other is by the employment of pumps driven by power. In some of the very large metalliferous mines the two are combined; the water from the lower levels is pumped up into an "adit," through which it runs away to a river.

The term "adit" has been explained in an earlier part of the book; it is used indifferently as an approach to the lode, from the surface, for the purpose of getting the mineral, and as a method of drainage. The most striking instance of the use of an "adit" is the Sutro tunnel that was excavated at a depth of 1700 feet below the surface and was run into the side of the hill to meet the lode, a distance of several miles. As its name implies, this adit is a large tunnel, virtually a ditch through which the water from the workings runs away to a river. The construction of the Sutro tunnel enabled the problem of getting rid of the water in the Comstock lode to be practically solved. In this case the water in the lower levels is pumped up to the level of the adit, and there runs away. The adit is slightly inclined towards the river.

A difficulty that is often met with in pumping water in deep mines, particularly in metalliferous mines, is the temperature of the water itself. All pumping comprises two

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operations : sucking the water up into the pump by the creation of a partial vacuum in the pump itself, and forcing the water that has been sucked up into the delivery pipe, from which it is forced to the surface, or wherever it is to be discharged. Under ordinary conditions and ordinary temperatures, immediately a partial vacuum is created in the pump the water to be dealt with rushes into the pump chamber ; where, however, water is at a comparatively high temperature, a certain quantity passes in, but a certain quantity of steam is formed, owing to the presence of the partial vacuum, and the existence of the steam prevents further suction. Various devices are employed to overcome this difficulty.

PUMPS

There are four forms of pumps employed in mines, known respectively as the Bucket pump, the Plunger pump, the Centrifugal pump, and the pumps on the Pulsometer principle. In all of them, as explained above, a certain quantity of the water to be pumped is first sucked into a part of the apparatus arranged to receive it, and it is then forced upwards through the pipe that is to carry it to the surface.

In the Bucket pump, as its name implies, there is a bucket, with a valve at the bottom opening upwards. The bucket works up and down inside a barrel or pipe ; and there is what is called a suction piece below. The bucket is attached to rods which are moved up and down by any convenient source of power. As the bucket moves down the valve in the bottom opens, and the water rushes through. At the end of the downward stroke the valve at the bottom closes, and the water which has passed into the bucket is carried upwards, and is delivered to the column of water in what is called the rising main, the column of pipes leading to the surface.

In the Plunger pump, again as the name implies, there is a plunger, a solid cylinder, or as the Americans would call it, a plug of metal, moving up and down inside a barrel, the pump barrel, very much in the same manner as the piston moves to and fro inside a steam cylinder. During the

Troubles in Mines

upward stroke of the plunger a valve opens in the bottom of the barrel, and the water from below rushes in. At the end of the upward stroke this valve closes, and as the plunger is forced downwards another valve opens, water being forced through it, up into the rising main.

Both bucket pumps and plunger pumps are sometimes arranged in pairs, one bucket or one plunger drawing water while the other is delivering. The plunger pump also is made for mining work in what is known as the "three-throw" form. Three separate pumps are arranged with their pump rods connected to a crank shaft, at equal angles

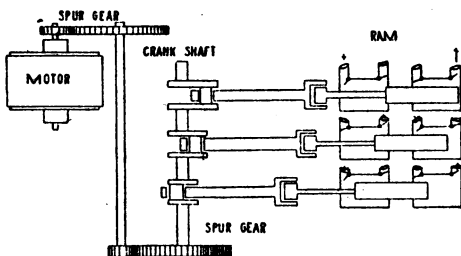


FIG. 21

Shows diagrammatically one of the latest forms of the three-throw or triple-ram pump. There are two pump cylinders to each ram, and as the ram moves up and down, one cylinder is always delivering water to the rising main, and water is being sucked into the other. The pump is driven by an electric motor, the latest arrangement.

around the shaft, so that the three pumps are working alternately, and a fairly constant stream of water is being delivered to the rising main. The three-throw plunger, or ram pump, is made in a number of sizes, from very small up to comparatively large, and is very useful for mining work, the three pumps being mounted together on a carriage, with some convenient source of power, such as an electric motor, and being arranged to follow the water down. Fig. 21 shows diagrammatically one of the latest forms of three-throw ram pumps, and Plate VII shows the actual apparatus.

Up till comparatively recently, and even now, the major portion of the pumping of deep metalliferous mines is done by the aid of either bucket or plunger pumps, worked by

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rods passing down the shaft, attached, sometimes through beams, to engines. The old Cornish pumping engine was one of the most economical power producers that was known up till recently. It consisted of a very large steam cylinder with a very long stroke, its connecting rod being attached to one end of a large beam. The beam was pivoted at its centre, and from its other end the rods working the pump depended. The usual arrangement was: Steam was forced into the cylinder, under the piston, forcing it to the top of its stroke, that end of the beam being forced upwards, and the pump rods with their buckets or plungers being forced downwards. On the completion of the stroke, a spray of water was admitted to the cylinder under the piston, the steam being instantly condensed, and a fairly good vacuum being produced, with the result that the piston descended, the pump rods being raised at the opposite end. In some cases the pump rods were attached directly to the connecting rod of the piston, and not through a beam. The connecting rod of a steam engine is the rod which transmits the power from the piston rod to the revolving crank shaft, the beam, or whatever is to employ the power; the piston rod is the rod which is fixed to the piston.

In some cases the pump is placed at the bottom of the shaft, or at the point from which water is to be raised, and steam is taken down to work it ; a combination of a steam engine and pump being fixed for the purpose. In other cases, again, the pump is placed at the point from which water is to be raised, and it is driven either by compressed air, taken down from the surface, in a similar manner to that for the rock drills, or by an electric motor. The electric motor is rapidly taking the place of all other methods of driving pumps in mines.

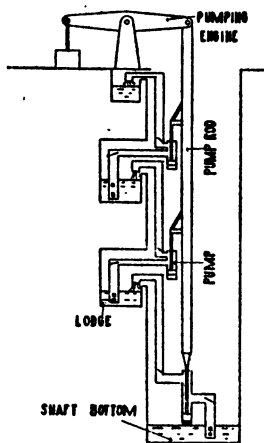


FIG. 22

Diagram showing the arrangement for raising water in deep mines, in three stages.

Troubles in Mines

In deep mines it is usual to raise the water to the surface in two or three stages. A pump at the bottom delivers the water to a lodge, or cistern, a certain distance up ; a second pump takes the water from that lodge to one a certain distance higher up ; a third pump takes it to the surface, and so on. Fig. 22 is a diagram showing this arrangement.

With modern plant, however, it is becoming more and more the practice to deliver the water straight to the surface. All the water from the different levels is usually allowed to run down to the lowest level, and is pumped up from there.

THE CENTRIFUGAL PUMP

It is only within the last fifteen years or so that the centrifugal pump has come to the front for use in mines. Before that date it was practically tabooed by mining engineers, because it would lift water only a short distance, and its efficiency was very low. By efficiency is meant the proportion of the power delivered to the pump that is actually expended in lifting the water. Lifting a certain quantity of water a certain height demands the expenditure of a certain number of horse-power ; in addition, the friction created by the water in flowing through the pipes demands a further expenditure of power to overcome it, and both the pump itself and the motor which drives it, whatever form the motor may have, also demand a certain amount of power to overcome their own friction, and for certain other losses. It will easily be understood that if a particular form of pump requires a very large amount of power for itself, or if it wastes in any other way a large portion of the power delivered to it, the actual cost of pumping any given quantity of water is considerably increased. The old forms of centrifugal pump were very wasteful. The modern form of centrifugal pump, however, is not only quite as efficient as the others that have been named, in many cases more efficient, but it is now employed for raising water through heights of 2000 feet, which enables it to be very largely employed in mining work. The centrifugal pump has also the great advantage that it runs at about the same speed as the electric motor. The bucket pump and the

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plunger pump run at very low speeds, ranging from four to five a minute, up to thirty or forty a minute in the older forms, and 150 to 250 in the improved Riedler pumps. Electric motors run at from 300 revolutions up to 1500 revolutions per minute. Only very large motors, those designed to furnish large amounts of power, would run at as low speeds as 300 revolutions ; but 500 and 600 revolutions per minute are quite common for the quantities of power required for centrifugal pumps employed in mines ; and these are the speeds at which centrifugal pumps run. Hence the combination of a centrifugal pump and an electric motor, with their axles directly connected, is a very convenient one and occupies a very small space. It can be run in practically any position—horizontal, perpendicular, or at an angle with the horizontal.

The centrifugal pump is very similar in a great many respects to the fans with which most of us are now familiar and that are now employed to ventilate offices ; in fact, the fan, the centrifugal pump, and the steam turbine are adaptations of the same principle. In the centrifugal pump there is an axle or shaft, carrying upon it a number of curved blades, somewhat similar to fan blades. The "impeller," as the axle with its blades is called, is carried inside of a chamber, to the centre of which the water to be pumped is admitted. The impeller is made to revolve very rapidly, and in doing so forces the water outwards, more water pouring in from the body that is to be pumped to take its place. The water that has been forced outwards by the impeller finds its way through certain curved channels provided for it, into which the delivery pipe, in exactly the same manner as in the case of the bucket and plunger, pumps. The centrifugal pump requires to be filled with water before it is started ; but once that is done, as long as the impeller is in motion a continuous stream of water is passing through the pump, from the cistern or lodge that has to be drained, to the rising main. The modern centrifugal pump, with a single impeller, will raise water 100 feet ; but by connecting a number of pumps together, the delivery of one forming the suction of the next, and so on, practically any required height may be obtained. In practice, as

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mentioned above, heights of 2000 feet are being daily pumped by the aid of centrifugal pumps worked by electric motors. Where there are a number of impellers, virtually of separate pumps, they are sometimes arranged half on each side of the electric motor. Fig. 23 is a diagram showing a centrifugal pump with its impeller driven by an electric motor. Plate VIIIA shows one form of the actual apparatus.

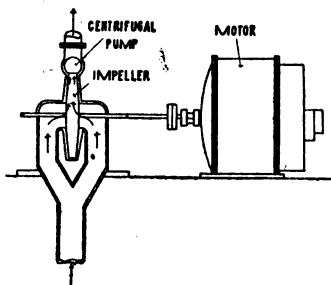


FIG. 23

Diagram of a single centrifugal pump, with its "impeller," driven by an electric motor. The arrows show the course taken by the water.

THE PULSOMETER PUMP

The great feature of the Pulsometer pump is its simplicity. It works by steam, and the arrangement is something on the lines of, though, to use a Hibernianism, quite different from, the Cornish pumping engine described above. It has been named the Pulsometer because it is constructed somewhat on the lines of the human heart. The apparatus is divided into two portions. Water is allowed to run into one portion, forming one side of the apparatus, until it is full, when the suction valve is closed. Steam then enters that side of the apparatus, and forces the water out through the delivery valve, the steam acting directly upon the surface of the water it meets. While this is in operation water is running into the opposite side. When the water in the side which is delivering has sunk to a certain level the supply of steam is cut off, and what remains is instantly condensed by contact with the water which remains; the suction valve is then opened, and that side fills with water. The water in the opposite side is then forced out into the delivery pipe, and so on. In the original form the Pulsometer itself, the entrance of the steam into the two sides of the apparatus, is controlled by a ball which rolls from one side to the other; in later forms of pumps, on somewhat similar lines, a valve of another kind is employed. The great ad-

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vantage of these pumps is, that no provision has to be made for getting rid of the exhaust steam, as there is with all other forms of steam engines, and nearly all forms of steam pumps. The exhaust steam is condensed in the pump itself. It, however, consumes a large quantity of steam for any given work, compared with other forms of steam pumps, and still more in comparison with the proportion of steam chargeable to electrically driven pumps.

POWER FOR DRIVING THE PUMPS

Power is furnished for driving the pumps by steam taken directly to them, by compressed air taken directly to them, by ropes, and by electricity. Steam is very wasteful if the pump is at any distance from the boiler, because a very large quantity of the steam is condensed in the pipes on its way to the pump. Compressed air is wasteful, because the pipes which convey it are very liable to leakage, and because the heat which is liberated in the air in the process of compression has to be dissipated, and is therefore wasted. In a few cases the air is reheated before being used underground, and the efficiency is thereby raised. Pretty well every other method of transmitting power, however, is giving way to that of electricity. Cables can be conducted down a shaft, along levels, and to wherever power may be required; and though certain difficulties attend the use of electricity, on the whole the cost of pumping by the aid of electricity is less than by any other source of power. Water is a great enemy to all electrical apparatus; but with the advance of science and engineering this has been largely discounted. As an instance, it may be mentioned that during the Transvaal war there were a number of pumps driven by electric motors at the bottom of some of the mine shafts for over two years, and when the mines were started to work, and the pumps and motors were recovered, they were immediately set to work again, after a little drying, the drying being effected by the use of the current itself.

VENTILATION OF METALLIFEROUS MINES

The ventilation of metalliferous mines is a very difficult problem; very much more difficult than that of ventilat-

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ing coal mines, and mainly because there have been no Acts passed regulating the quantity of air that must be passing in any particular part of the mine. The ventilation of coal mines will be dealt with later on.

By ventilation is meant the continual changing of the air in every part of the mine, so that men and animals, where they are employed, have good air to breathe. There are several agencies at work tending to vitiate the air. There is the expiration of carbonic acid and other deleterious substances by the men employed in the mine ; there is the carbonic acid produced by the combustion of the candles and lamps employed for lighting, except where the mines are lighted by means of electric lamps ; and there are the products of combustion, the noxious fumes produced in the burning of the charges employed in blasting. In all mines also the decaying timber gives off carbonic acid gas, and in many metalliferous mines, in sulphur mines in particular, and in some iron mines, carburetted hydrogen gas, similar to that which is found in coal mines in such large quantities, is also given off. In deep mines the heat at the lower levels is a great source of trouble to the workers, particularly where the mine is also wet. Dr. Leonard Hill has recently shown by his exhaustive investigations that it is the wet-bulb temperature which governs the ability of men to work. The quantity of moisture, of the vapour of water, that air can take up varies with its temperature, and increases very rapidly as the temperature rises. In comparatively moderate temperatures, if the air is "saturated," as it is called, with moisture, working is difficult, because the perspiration produced upon the skin by the exertion of work cannot evaporate, and consequently the body becomes intensely hot. It will easily be understood that as the temperature rises, if also the air is saturated, or nearly saturated with moisture, the difficulty of working in it increases. The amount of moisture present in any body of air is found by the hygrometer, or by the difference between the temperatures shown by the wet and dry bulbs of two thermometers. The bulb of one thermometer is exposed to the air directly, and the bulb of the other is kept wet by a rag dipping into a little reservoir of water. The evapora-

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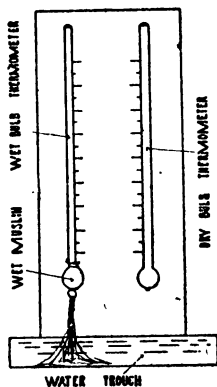


FIG. 24

Arrangement of wet and dry bulb thermometers, to show the humidity of the atmosphere.

tion of the water from the rag lowers the temperature of the wet bulb, as it is called ; and the lower the humidity, the smaller the percentage of saturation of the air, the greater is the evaporation from the wet rag, and the lower the temperature shown by a wet bulb. When the temperature shown by a wet bulb is high, it shows that the temperature of the atmosphere in the neighbourhood is high, and if the difference between the two is small, it shows also that the air is highly saturated. A wet and dry bulb hygrometer is shown in Fig. 24.

In small metalliferous mines, it will be remembered, there may be only one shaft, with levels running out on each side of it, into the lode, the levels ending in rock walls. For efficient ventilation an air circuit is required, as will be explained when dealing with coal mine ventilation, by which the fresh air entering the mine passes through all the places where men are working, and where noxious gases of any kind are given off, and returns to the surface by another route, having collected all the deleterious substances in the air on its way. In metalliferous mines, where the levels end in rock walls, there is no such air circuit, and the utmost that is obtained, except where special arrangements are made, is a circulation caused by the warmer air rising to the roof of the level, and being displaced by the colder air entering the level. In some cases the level rises as it recedes from the shaft, and in those cases natural ventilation, as it is called, is very difficult. The compressed air which is used for driving the rock drills is of great service in assisting the ventilation, as the exhaust from the drill, passing out into the atmosphere of the mine, consisting of pure air from the surface and expanding very rapidly, sets up a certain flow of air. In other cases, ventilation of levels has been effected by carrying a pipe from the shaft to the end of the level, as shown in Fig. 25. The fresh air from the

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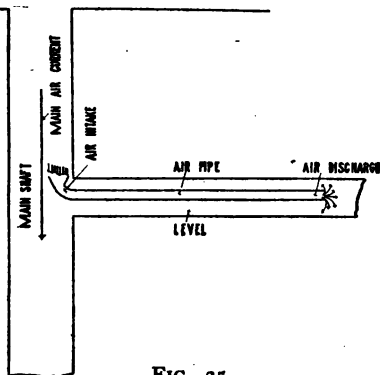


FIG. 25

Diagram showing the method of assisting the ventilation of levels by pipes carried from the shaft to the end of the level.

ing into two columns. The warm air usually separates out and rises to the surface, while the colder air from the surface finds its way down independently. In some cases the separation is assisted by a division in the shaft, as shown in Fig. 26. Where there are only two shafts, the same arrangement can be made as with coal mines, one shaft bringing fresh air to all the levels, and the other carrying the vitiated air up to the surface; but such an arrangement is very rarely carried out. As a rule the air is left to find its way down either of the shafts, and up either of the shafts, at will. In recent years, since the use of electricity in mines has been developed, fans driven by electricity have been placed in different parts of metalliferous mines to direct the air, so as to produce a more or less good circulation.

shaft being delivered at the end of the level sets up an air current, which tends to carry off the noxious fumes, etc. This is not very perfect ventilation, as the foul air from the level mixes with the other air in the shaft, some of which finds its way back into the level again.

In the shaft itself, where there is only a single one, a certain amount of natural ventilation is carried on, by the air separat-

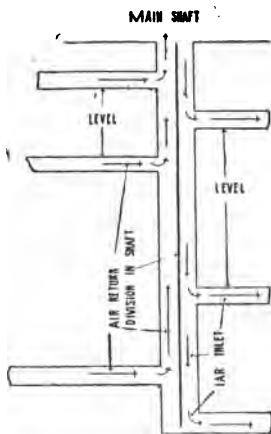


FIG. 26

Diagram showing how ventilation may be assisted, where there is only one shaft, by dividing it in two.

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Furnaces have also been employed to a small extent in metalliferous mines to produce ventilation. The furnace, as will be explained, was used for a long time in coal mines, and is still to a small extent. The object of the furnace is to produce a column of warm air that will ascend a shaft in the neighbourhood, and so cause a circulation of air. In the case of two shafts, for instance, if a furnace is placed near the bottom of one of them, and it is arranged for the air from the bottom levels or a portion of it to pass over the furnace, a column of hot air will be created in that shaft, and what mining engineers call a "motive column" will be

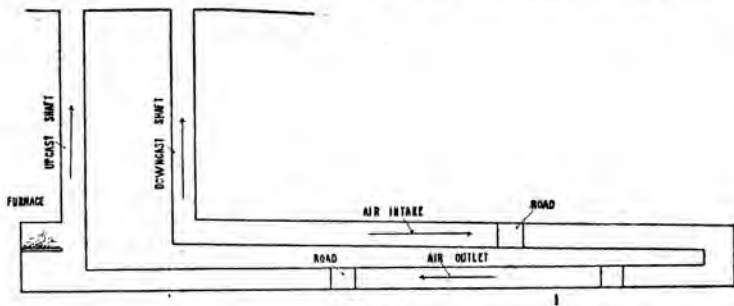


FIG. 27

Diagram showing the method of furnace ventilation.

produced, cold air passing down the other shaft. The motive column is the difference in the weight of the air in the fresh air shaft and that in the vitiated air shaft, or as it is usually expressed, in the downcast and upcast shafts. Fig. 27 shows the arrangement of furnace ventilation. Unfortunately this arrangement only partially provides ventilation, as it does not extend to the levels in the same manner as in coal mines, as will be explained.

For the ventilation of levels, winzes and rises are often employed. A winze, it will be remembered, is a small shaft let down from one level to that below it, while a rise is a similar shaft pushed up from a level to that above it. It will be seen that the provision of such a shaft tends to assist the circulation of air through the two levels, up to

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the winze or rise, the motive column being the difference in the weight of the air in the shaft between the two levels. This again is a very imperfect method compared to that employed in coal mines.

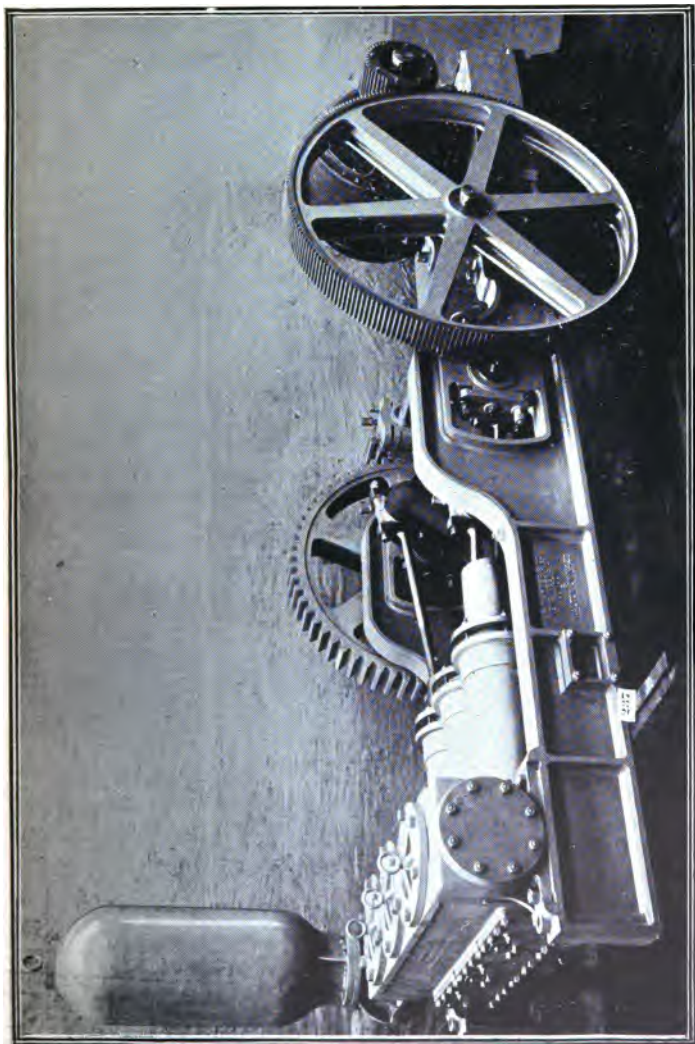
Where there are three or more shafts, as in the large metalliferous mines, the ventilation is more or less haphazard, though, as explained above, it is gradually being taken in hand by the aid of fans, etc.

CHAPTER V

HOW THE METAL IS EXTRACTED FROM ITS ORE

IRON

FOR several of the minerals that have been described not much treatment is required. In the case of iron ore, for instance, it is taken directly to the ore bins alongside of the blast furnaces, which are usually placed within easy reach of the iron ore mines. Around Middlesborough, for instance, which is close to the Cleveland iron ore deposits, there are a large number of blast furnaces; again, there are a number in North Lancashire and Cumberland, near the hematite deposits there; and there are iron smelting blast furnaces at different parts of the coast, where the ore brought from overseas is smelted. There is not space here to enter into the process of smelting the iron ore. It will perhaps be sufficient to say that the blast furnace is practically a huge chimney, with a grate at the bottom, and with an arrangement for pumping air through the burning mass on the inside of the furnace, continuously. Iron ore, coke, and limestone are fed into the furnace in certain definite quantities, a fire is lighted on the grate at the bottom of the furnace when it is first started, and the whole is kept working by the "blast," from which the furnace takes its name. Very large engines are employed, continually forcing air through the furnace, the air having been previously heated and, in the latest modern arrangements, dried by the aid of refrigerating apparatus. The coke combining with the oxygen of the air furnishes heat, which raises the temperature of the whole mass and causes the iron to separate from the oxygen with which it is combined



THREE-THROW RAM PUMP DRIVEN BY AN ELECTRIC MOTOR

PLATE VII

To face page 64



PLATE VIII

GOLD-DREDGING APPARATUS



CENTRIFUGAL PUMP DRIVEN BY AN ELECTRIC MOTOR

PLATE VIII A

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in the ore. The limestone which is added is necessary as a flux ; that is to say, to enable the mass to run freely. At certain periods, the molten iron which falls to the bottom of the furnace is run off sometimes into a kettle provided for it, in which it is taken to the steel works, sometimes into what are called beds, a large area filled with sand in which moulds have been made, the masses of iron which result being called pigs, and the whole mass of iron—the “ pigs ” with their connecting pieces—being called the “ sow and pigs.” After the iron has been run off, the dross or slag is also run off. The slag is more or less stone ; it is used for repairing roads ; it is used also, after passing through another process, for the insulation of cold stores ; and it has been made into domestic utensils, vases, etc.

Gold and tin ores are subject to very much the same process, as also are certain other ores. With both gold and tin, the rock in which the ore is held is very hard, and it is also heavy. Tinstone may usually be detected by its weight. As mentioned in a previous chapter, the ore after being broken down by blasting is filled into the mine wagons or skips, is hauled along the levels, and then up the shaft. From the shaft it passes to the crushing apparatus. The whole of the rock has to be ground up to a very fine powder, and the “ native ” gold or tin, or the compound containing the gold, has to be extracted from the fine dust produced, by the processes to be described. First the rock passes to a stone breaker. In certain cases it is passed over what is called a “ picking belt ”—a wide belt which receives the ore from the mine wagon and which carries it to an ore bin in the neighbourhood of the ore breaker. The object of the “ picking belt ” is to enable pieces of rock that are known, and that can be seen at sight not to contain mineral, to be thrown out. Men, and in some cases women, stand on each side of the “ picking belt ” and pick out what is not required. At some mines a picking table is used in place of the picking belt. It consists of a large iron disc or table, supported in the centre, and perforated by a number of holes to allow moisture and dust to pass through. Men or women stand round the table ; the ore is delivered to it at one point, and the men and women throw out the stone

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and other useless material as it comes round to them ; and when it arrives at another point, the ore remaining is carried off into a chute. In the old days hand picking was carried out to a certain extent underground, but in these days there does not seem to be time for it. In the older mines also, a certain amount of breaking up by the aid of sledges was carried on on the surface, but with the advance

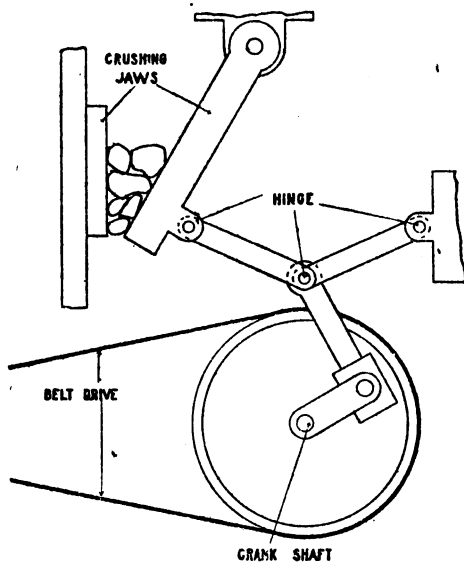


FIG. 28

Section of a stone breaker, showing the movable and stationary jaws which crush it, and the belt for driving it.

of the use of machinery it is found more economical to carry the rock straight to the machines that will deal with it. The first machine to which the ore is usually subject is called the crusher or stone breaker. It has various forms, according to the ideas of inventors, but there are always two jaws, one stationary and the other movable. The rock is fed into the space between the jaws, and the movable jaw working to and fro crushes it into pieces of a

given size. Fig. 28 shows what is called a section of a stone crusher. The two jaws between which the stone is crushed will be seen, the moving jaw being worked by the aid of any convenient source of power, a steam engine, an electric motor, or a belt from any running shaft.

Another form of rock breaker that is gradually taking the place of the jaw crusher, was first introduced, the writer believes, by Gates, and is largely employed. In the Gates

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rock breaker, the working portion of the apparatus consists of a perpendicular axle, carrying what may be termed crushing tools, pieces of hard steel forming, with the axle, part of a cone. The whole thing revolves rapidly inside of a conical chamber provided for it, into which the rock to be crushed is fed, the result being, it is claimed, a more rapid breaking up of the rock and its being broken to smaller sizes. The chamber in

which the conical crushing head revolves is fitted with what are called "liners"—pieces of hard cast iron or steel that can be removed when worn. The revolving apparatus carries similar pieces of hard cast iron or steel that can be renewed when worn, and the ore to be crushed passes between the two. Fig. 29 shows what is called a section of the Gates crusher. The vertical axle is caused to revolve by a horizontal axle connected to it mechanically by means of gear wheels.

After the stone breaker, or the Gates crusher, the ore is further broken up, in a great many cases, by being passed between pairs of rolls. The rolls have again hard steel renewable surfaces, as the wear is considerable; and one of them is fixed, while the other can be moved nearer to or farther from the stationary one, so as to deal with different sizes of rock.

It will be understood that the whole of the machinery in connection with a gold or tin mine is designed to gradu-

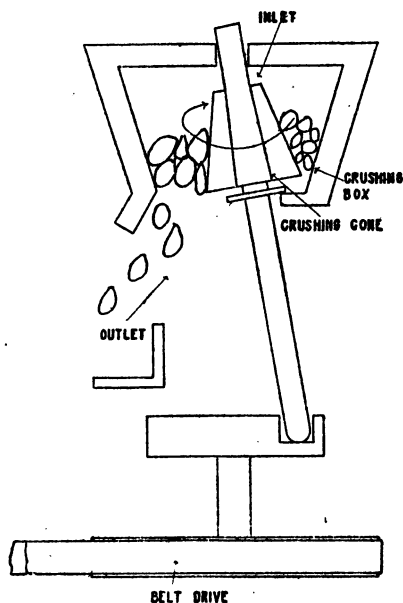


FIG. 29

Section of a Gates gyratory rock crusher

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ally reduce the large lumps of hard rock to the very fine dust or powder necessary to enable the gold or tin or other metal to be extracted from it. The stone breaker, or the Gates crushing machine, reduces the rock to a certain size, and then the rolls break it up into a still smaller form. Fig. 30 shows a section of a pair of rolls.

There are, again, various forms of rolls, and they are designed, as explained, to reduce the rock gradually down to small sizes. Several sets of rolls may be employed at one mine, after the first breaking up of the rock. They will be known as roughing rolls, medium rolls, and finishing rolls.

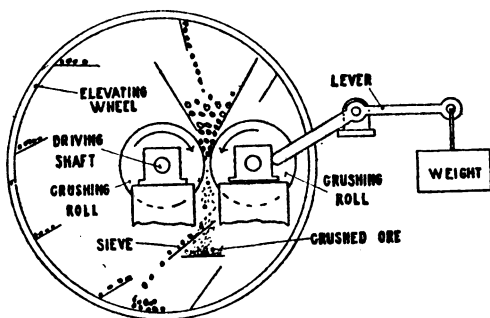


FIG. 30

Section of rolls for crushing the ore.

After passing through the rolls, the rock is subject to a process called "screening." Screens are of various forms, sometimes cylindrical, sometimes rectangular, and they are built up of metal rods, or wire, or metal plates, according to the work they have to do. The screen, for instance, which has to separate the pieces of rock measuring $\frac{1}{2}$ inch across from that measuring only $\frac{1}{8}$ inch, will be built up of metal rods of a certain size, while the next screen will be built up of smaller metal rods, and the next again of wire. It is arranged that the ore coming from the stone breaker and passing through the roughing rolls, then passes through a screen which throws out the large pieces measuring $\frac{1}{2}$ inch and upwards, and passes them on, usually by means of a

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travelling belt, to the next set of rolls ; the smaller stuff, which measures $\frac{1}{8}$ inch across and less, passes through a smaller-mesh screen, and is conveyed to the finishing rolls. Fig. 31 shows a rotating cylindrical screen delivering on to a travelling picking belt. The ore which is passed through the screen which separates out that which measures $\frac{1}{8}$ inch or less across, all that passes through being carried on to the finishing rolls. After being crushed by the finishing rolls the ore is carried through the finer screen, and thence to the storage bin, ready for the next process. In all arrangements of this kind the larger pieces, which do not go through the particular screen attached to the rolls, are delivered to a travel-

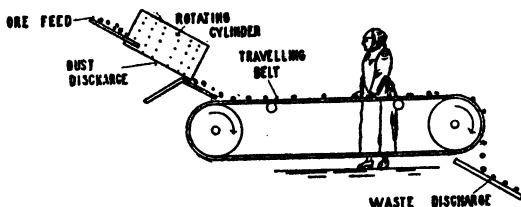


FIG. 31

Diagram showing a rotating screen delivering the ore on to a travelling belt, which is also used for picking.

ling belt which carries them back to the rolls from which they came, and they are passed through a second time. This goes on at each set of rolls.

Travelling belts, and what are called elevators, are very much employed about metalliferous mines. A travelling belt is shown in Fig. 31. It is a belt of canvas or other material, according to the substance to be dealt with, very much like the belts used for driving machinery, but it is very much wider than the usual run of such belts. It is arranged to run horizontally between two places, and often performs the double office mentioned above, conveying the ore from one point to another, and providing a convenient means of removing material that will not pay for working up. The belt is bent round rollers at each end of its travel, and runs on rollers at certain distances between. Where it

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is not used as a picking belt, the ore that is to be delivered to any particular spot falls on to it, and is simply carried away to that spot. Belt conveyors are often combined with elevators. An elevator is shown in Fig. 32. It consists of a number of buckets, as shown, attached to an endless chain, which is kept continually travelling round and round, very much in the same manner as the travelling belt is. The elevator may work in a perpendicular position, or at any angle inclined to the perpendicular ; it occasionally works in a horizontal, or nearly horizontal, position. The

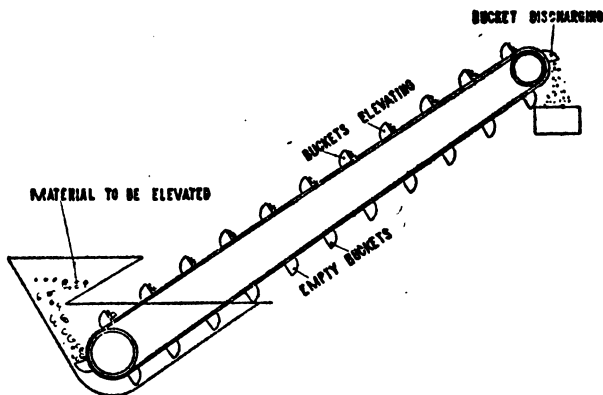


FIG. 32

Diagram of a bucket elevator. It consists of a chain, carrying buckets at intervals, the chain being kept continuously moving over two pulleys, or rollers.

travelling belt occasionally works also in a position a little out of the horizontal, so that the material is conveyed to a higher level. By means of travelling belts and conveyors, the ore, or any part of it, may be transported from point to point automatically, and this is what is done. The large lumps fall out of the screen, for instance, on to a belt, and are either conveyed by it straight back to the point from which the rolls are fed, that it recently passed through, or it may deliver to one of the buckets of an elevator, which, again, may deliver it to another belt at the top, and so on.

For further crushing, for reducing the ore to very fine

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powder, the older method consisted of a number of stamps. Anyone who has stayed at a Cornish town, in the neighbourhood of mines, will have been struck by the noise resembling the roar of the sea that is going on day and night. A very large number of stamps are still employed in connection with gold and tin and other metal mines all over the world ; in particular a very large number are employed on the Rand, one very large proposition—the Simmer and Jack—employing as many as 200 stamps. The stamp consists of a perpendicular rod, which in the old days was made of wood, but is now of iron, carrying at its lower end what is virtually a hammer. The hammer consists of what is called the head, a hollow cylinder of iron which is keyed on to the perpendicular rod, and the shoe, a removable piece of hard steel which is keyed on to the head. The head with the shoe, when not at work, rests upon what is called the die, which is virtually an anvil, another block of hardened steel. The process of stamping consists in raising the head and shoe and the vertical rod together a certain distance, and then suddenly allowing them to drop upon the die. The stamp, as the whole apparatus is called, is raised by means of a “tappet” and a cam. The “tappet” is another cylinder of iron held on a portion of the perpendicular rod some distance above the head and shoe, and with projections which engage with the cam. The cam is a piece of apparatus very frequently employed in engineering to move rods a certain distance, as in the case of opening steam valves. The cam may be described as a piece of iron or steel, shaped as shown in Fig. 33. As will be seen, it has two wings, carried upon a central boss, as engineers term it. There is one of these cams to each stamp, the whole of the cams being fixed upon a horizontal iron rod which is continually revolving

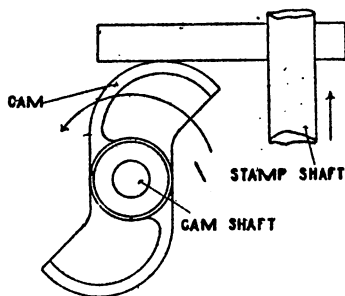


FIG. 33
Cam for raising the head of the stamp and dropping it suddenly.

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while the stamps are at work. The points of the *wings* of the cams are arranged to engage in the projections of the "tappets," so that as the cam moves round the "tappet" and the stamp rod are raised gradually. At a certain point of the revolution of the cam it leaves the "tappet," and the stamp then falls directly upon the die, crushing whatever may be upon it.

Stamps are usually arranged in groups of five or ten, and the dies are fixed together, the five or ten, in what are called mortars, virtually enclosing boxes, with foundations of sufficient strength to stand the continual strain of the falling stamps. On one side of the mortar box is a screen consisting of a metal plate with a certain number of holes, and on the other side is the entrance for the ore that is to be crushed,

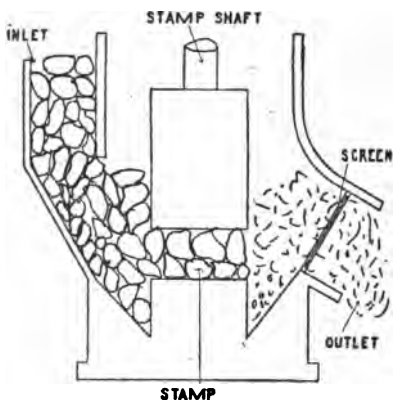


FIG. 34

Mortar box for a group of stamps.

Where wet crushing is the rule a stream of water enters at the same place. The stamp rods are held in a framework built up either of wood, iron, or steel, so that the perpendicular rods move up and down in guides of sufficient strength to stand the strain of the continual dropping. Fig. 34 shows the mortar box of a group of stamps, and Plate IX a view of a small stamp mill in the Mozambique. The stamps are usually about 1000 lbs.

weight; that is to say, the heads, shoes, and rod. The stamps in a particular group or mortar box are raised and dropped alternatively, those next to each other not being usually dropped consecutively. Fig. 35 shows a group of stamps.

The ore which has been broken up to a certain size, cubes of about $1\frac{1}{2}$ inches, or sometimes smaller, is fed continuously into the mortar boxes, and is there reduced to very fine

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powder, or "slime," as it is termed. It overflows from the mortar box, through the screen mentioned above, on to, in the case of gold and silver, a copper plate that has been cleaned and rubbed over with mercury, or amalgamated, as it is called; any of the gold or silver that is present, and that has been released by the crushing action, adheres to the mercury on the copper plates.

The deposit upon the copper plates is scraped off from time to time, the plates being re-amalgamated and replaced in position, and the gold "amalgam," as it is called, is subjected to heat, in the process known as smelting, the mercury being driven off in the form of vapour, which is condensed and used over again, the gold being recovered.

A modern development of the stamp, which is used at the Lake Superior copper mines and elsewhere, is the steam stamp. It is virtually a steam hammer, and is worked by a steam cylinder, just as the steam hammer is. There are the same die and mortar, etc., and the same head and shoe, but the rod which carries the head and shoe is attached to the piston of a steam cylinder. There are two cylinders to the steam engine, and it is so arranged that steam is admitted on different sides of the pistons, so that the stamp is alternately raised and dropped, just as with the older form in which the "tappet" and the cam are employed.

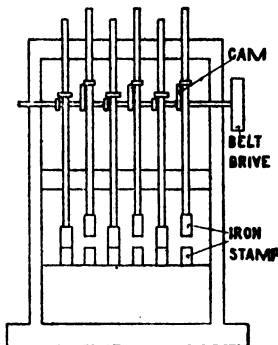


FIG. 35

Diagram showing group of stamps in a stamp mill. Alternate heads, it will be seen, are suspended, ready to fall.

THE TUBE MILL

An apparatus that is steadily making its way, to displace the stamp mill, is the tube mill. It consists of a large iron cylinder, which is caused to revolve by means of power applied to toothed wheels on its outside. Inside of the cylinder are a number of balls, sometimes of steel, and in many cases of stone. The ore which has been crushed to

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the size mentioned, $1\frac{1}{2}$ inches or thereabouts, is fed into the cylinder at one end, and is subject to a continual crushing process by reason of the revolution of the cylinder, and the motion imparted to the balls or stones inside. The result is the production of fine sand or "slimes," just as from the stamp mill. The tube mill is claimed to be very much more efficient than the stamp mill, though, as usual, the stamp mill still finds many advocates. In gold and silver mining, the sand or slimes from the tube mills is made to pass over amalgamated copper plates, where some of the gold is trapped, as with stamp mills.

CONCENTRATING THE SLIMES

After the ore, or the rock in which the metal is contained, has been reduced to a fine powder, the next object sought to be attained is the extraction from the fine powder of the metal where it is native, or the compound in which the metal sought is present. This process is known as "concentration." The first part of the concentration is the removal of the gold or silver by the aid of mercury as the ore leaves the stamps or tube mills, as already explained. The next process which is used in many cases is what is known as "jigging." In "jigging" water is employed together with what are practically screens, of various meshes, together with a jigging motion, to separate the material containing the metal from the other useless material. "Jigs" are of various forms, but they all work on the same lines. In all cases the crushed ore from which the metal is to be separated is delivered on to a moving screen, water also being arranged to play over the screen, the result being that a certain amount of the metal that is being sought for passes through the screen and is carried off to the next process. That which passes over the screen is also dealt with by another process. It will be understood that in metallurgical working, in those cases where metal is being extracted from ore, and where the metal is present in only very small quantities, as in the case of gold and silver, lead, tin, etc., the whole of the processes are repeated over and over again. Thus, in the earlier processes of crushing the rock which

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does not pass through the holes in the screen is carried back and recrushed; and again, in the later processes, the ore which passes over a screen or separating apparatus is carried back, and is resubject to somewhat the same process. From the "jigger" the ore passes to what is called the buddle. Like other old forms of apparatus, the buddle is gradually being displaced by improved methods. The buddle consists of a circular pit into which the "slimes" are delivered at the centre. Four arms, carrying, in some cases brushes, and in some cases teeth, are fixed at right angles,

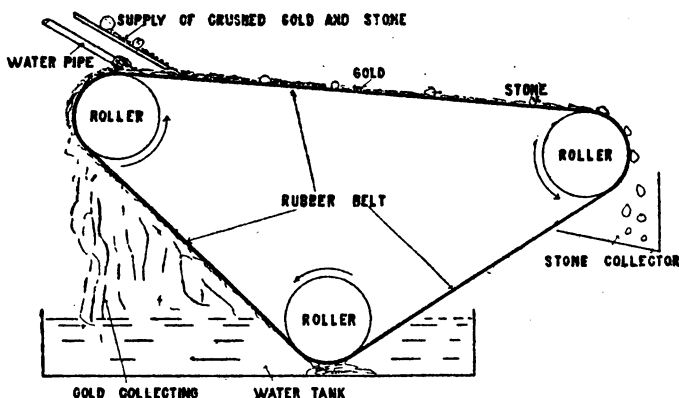


FIG. 36

Section of Frue Vanner on apparatus for separating the gold and silver from the dross.

across the buddle, and to the revolving perpendicular shaft in the centre. As the arms revolve they spread out the slimes, and they also sort them out. The slimes after treatment in the buddle are found to be richer towards the centre, and the deposit in the buddle pit is divided up, the richer inner rings being carried to another buddle, where they are treated in the same manner, the next lot being also treated in another buddle, and the outside being subject to further treatment intended to cover the small quantity remaining. The buddle is of various forms: it is sometimes convex, sometimes concave, and so on. After the buddle, the

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crushed ore is subject to various processes, all designed to separate the metal from the "gangue," or dross; the most important of which is that known as the "Frue Vanner." A section of the "Frue Vanner" is shown in Fig. 36. The "Frue Vanner" illustrates very beautifully the methods employed to separate the metal from other substances, by the aid of water and by the difference in specific gravity, the difference in the effect of a stream of water upon bodies of different weight and different volume. The apparatus consists essentially of a wide rubber belt, with its edges turned up, so as to form a kind of trough. It is bent round pulleys, as shown in Fig. 36, and the ore is delivered to the belt some distance from the upper end, while jets of water are made to impinge upon the belt still a little higher up. The belt is made to travel by the aid of power in the opposite direction to that in which the stream of water and the stream of crushed ore would run under the ordinary action of gravity. The heavier particles of the ore containing the metal cling to the belt, in spite of the action of gravity and of the water, and are carried over the top pulley shown, and thence round into a tank of water shown below, where they are deposited, and afterwards dealt with. The waste material, that which is not so rich in metal, passes on to the other end of the belt, and is delivered to another apparatus to be subject to further processes.

THE CYANIDE PROCESS

The cyanide process of extracting gold and silver from the ore has been developed from the practice of electroplating. In electroplating cyanide of potash is used very largely for making solutions of gold and silver and copper, because those metals, and in fact nearly every metal, is so readily dissolved in it. Cyanide of potash contains the deadly substance hydrocyanic acid, known commonly as prussic acid. It is a very dangerous substance to handle, but it is used in gold and silver mining districts in enormous quantities.

At first the cyanide process was employed to extract from the "sands" and "slimes," as they are called, the

How Metal is Extracted from Ore

very last particles of gold or silver. It is gradually, however, making its way to displace some of the other processes, in some cases the rock being crushed to a very fine powder and subjected to the cyanide process at once.

In the cyanide process the "sands," or "slimes," are conveyed to tanks of various sizes—cylindrical vessels open at the top, having filters at the bottom, and what are called "gates" for discharging the sands and slimes after the process is completed. The sands or slimes, and in some cases the ore in larger form, are delivered to the cyaniding tanks, and are distributed over the tank as evenly as possible. One great object in all of these processes is to make sure that the metal-bearing ore is evenly distributed, so that the whole of it is subject to whatever process may be in operation. The sands or slimes are sometimes first washed before the cyanide solution is applied; and again in other cases, in the crushing process, a very weak solution of cyanide of potash is employed in place of ordinary water. When the cyanide of potash is to be applied in the tanks, a certain quantity is sometimes pumped into the tanks from below, forced up through the mass of crushed ore to a certain height, and then a further quantity is delivered in the form of spray from above. In other cases the whole of the cyanide solution is delivered from above. The cyanide solution employed varies in strength, but the tendency is to employ weaker and weaker solutions, as these are found to operate better, to more completely extract the gold, and to waste less cyanide. It will be understood that a certain quantity of cyanide of potash is used up, or wasted, with every tankful of crushed ore. When the "standard" solution, as it is called, has been delivered to the whole of the tank, it is usually allowed to soak for a certain time, depending upon the character of the ore, and other matters. After the soaking period, what is known as "leaching" is allowed to proceed. The cyanide solution slowly percolates through the mass of crushed ore, carrying with it the gold which it has dissolved from the ore, and passing down through the filter to a tank provided for it. The cyanide of potash has been converted in the tank into a cyanide of gold, or more correctly, into a compound salt containing gold and cyanide

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of potash. Other operations are necessary in the cyaniding process. A certain quantity of oxygen is required, and that is furnished by air which is delivered to the tanks. In some cases the crushed ore is subject to agitation by air before the cyanide is applied. After the standard cyanide liquor has been drawn off, water is passed through the crushed ore in the tanks, drawing off the remainder of the cyanide, and with it the remainder of the gold ; and this is continued until all the gold has been extracted.

The next process is to break up the compound of cyanide and gold, and to extract the gold in a form that it can be dealt with in the smelting furnace. This is accomplished by the aid of zinc. The zinc may be applied in the form of shavings, or in the form of dust. In either case the gold is deposited upon the zinc, and the amalgam of gold and zinc is carried to the smelting furnace, where the zinc is driven off by heat, and the gold recovered in the usual way.

The process for recovering silver is very similar to that for recovering gold. It often happens that silver and gold are together in the same ore, and also that other substances are present.

Silver is also recovered in some cases by what is called the chlorination process. Silver is readily dissolved in hydrochloric acid, the process being something on the same lines as that with gold and cyanide. The silver is first dissolved by the chloride, and is later removed from the chloride that is formed.

There is a process for removing gold from the cyanide solution by the aid of electricity. The solution is led into tanks containing plates of iron and lead, and an electric current is passed through the tanks, from the iron to the lead. The current splits up the solution and deposits the gold upon the lead plate, from which it is removed later by smelting. The final process with all metals is some form of smelting, in which, by the aid of heat, the metal that is being worked for is obtained in a more or less pure form. Plate X is a view of a cyanide plant in the Mozambique.

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A TYPICAL GOLD MINING PLANT ON THE RAND, SOUTH AFRICA

The mine has two shafts, one 3100 feet deep and the other 3700 feet deep. Both shafts are vertical, and they are arranged to strike the lode at a considerable depth. An incline, or slope, in the mine connects the two shafts, and from it six levels are driven off in both directions. The mine cars, or skips, are hauled along the levels by ropes. Each shaft has seven compartments, and the hoists or winding drums are worked by electricity. The shafts are 1500 yards, or nearly a mile, apart, and the "reduction works," in which the lode is treated, are situated near the deeper of the two shafts. The ore is brought to the surface in skips holding five tons each, and is "dumped," as it is called, over a screen or "grizzly," which screens to $1\frac{1}{2}$ inches. The ore from the other shaft is drawn to the reduction works by locomotives. Five conveyor belts carry the crushed ore to five screens, where the finer ore is separated, the coarser being carried back to the crushers. It then passes along five sorting belts, each 72 feet long, where as much of the waste as can be seen by the eye is picked out; and from the sorting belts it is carried to jaw-type crushers, and thence to a battery of 160 stamps. From the stamps the "pulp," the crushed ore, is carried along to two coarse sand pumps, which deliver it to six tube crushing mills. The crushed ore from the tube mills passes over amalgamating tables. From the amalgamating tables the pulp is carried by means of belts,

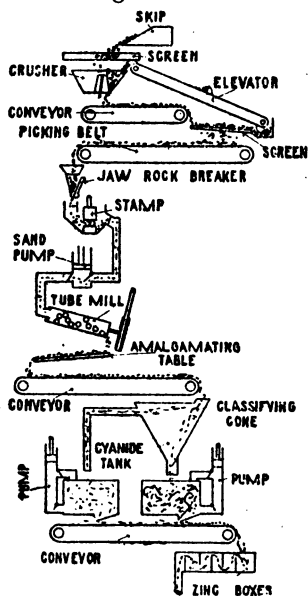


FIG. 37

Diagram showing the course of the ore from the mine skip through the various crushing, transporting, and extracting apparatus.

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through classifying cones, to eight cyanide tanks. Each tank is 60 feet in diameter, and holds 1180 tons. The finer pulp, the slime as it is called, is delivered to other tanks, and all are subject to the cyanide process. From the cyanide tanks the cyanide solution is carried to the zinc boxes, and thence to the filters, as already explained.

The sand which has been treated is discharged into buckets and carried by an aerial railway to a sand dump, similar to the dumps or tips that those who have travelled in colliery districts in the United Kingdom will be familiar with. Fig. 37 is a diagram showing the course of the ore from the mine to the furnace, and Plate XI is a general view of a mining plant on the surface.

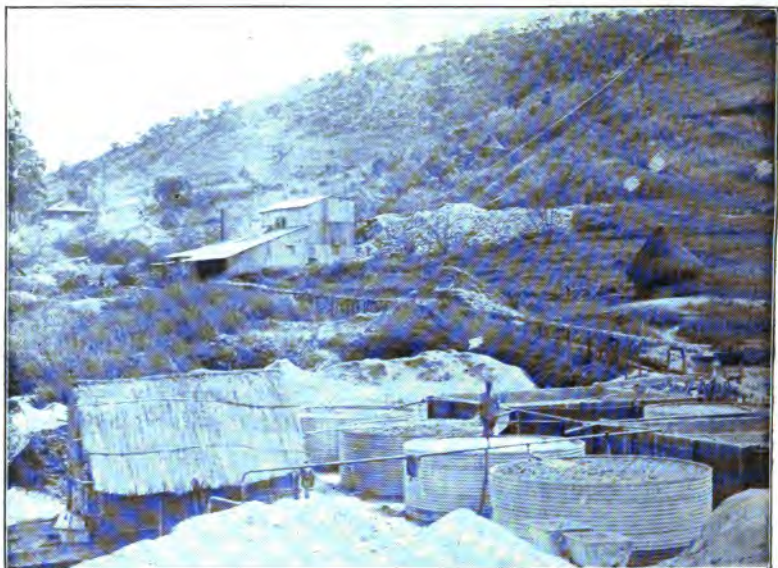


FIVE-STAMP BATTERY, WEDNESDAY MINE, MOZAMBIQUE

PLATE IX

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(Reproduced by permission of the Editor of "South African Engineering.")



CYANIDE WORKS AT THE GUY FAWKES MINE, MOZAMBIQUE

PLATE X

(Reproduced from "South African Engineering," by permission of the Editor.)



A ROADWAY IN A NORTHUMBRIAN COAL MINE

PLATE XA

CHAPTER VI

COAL MINING

AS explained in an earlier chapter, the coal as we now know it was formed from plants which grew in basins, and the seams lie at varying inclinations, the seams being wrapped round the basins, so to speak, from the outcrop, which is usually on a hillside, down to the bottom of the basin. As will be seen, the depth of the coal seam from the surface depends upon its position in the basin, and the "dip," as it is called, or the inclination of the seam. Near the outcrop the depth is very small, and it increases as the outcrop is receded from. Further, the depth of different seams varies considerably. In the early days of coal mining the seams near the surface, 50 yards and 100 yards deep or so, were worked; but as time has gone on, the depths of the available coal seams have steadily increased, till now those worked reach in some cases depths of 1000 yards, while depths of 700 and 800 yards are quite common. In coal mining it is usual to lease an area or, as it is called, a royalty, the right to abstract the coal from all the seams within that area. Usually a certain fixed sum is paid upon each ton of coal that is raised to the surface, besides other charges. In modern practice also, two shafts are now usually sunk, close together, in some favourable portion of the area to be worked. As the cost of sinking shafts is very heavy, it is now the common practice to sink them at the highest point of the area to be worked, or as near there as possible. In a few cases shafts have been obliged to be sunk at lower points. Two shafts are necessary, because of the requirements of ventilation. The ventilation of coal mines stands upon a very different footing from that of metalliferous mines. With metalliferous mines, as already

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explained, there is no Act of Parliament, nor of any public body in other countries, obliging ventilation to be carried out in a certain way. With coal mines, the enormous loss of life that has taken place when explosions of gas have occurred has led to very drastic rules being enacted by successive Acts of Parliament. As explained in a previous chapter, in the process of transition from the plant condition to that we know as coal, large quantities of carburetted hydrogen gas are formed. The particular gas formed, and that is so dangerous, is called "methane," and it forms a large proportion of the gas we burn for illumination and heating in our houses. As some householders have found to their cost, when they have allowed gas to escape and have inadvertently ignited the mixture of gas and air that has been produced, methane when mixed with certain percentages of air is very explosive. Fortunately the explosive boundaries, if the term may be used, are strictly limited. With a smaller percentage of gas in the air than 5 per cent no explosion can take place, while with a larger quantity than 15 per cent, again no explosion can take place. In some cases these limits have been slightly exceeded, but for practical purposes those are the figures. The gas formed is stored in the pores of the coal seams under pressure. In the shallower seams, those that were worked in the early days of coal mining, there was not much gas present, because it was able to escape into the atmosphere through the overlying strata, and though explosions did frequently occur, they did not do much harm. Old miners have told the writer of the practice in those days. A miner would go to his working place with a naked candle, and would carefully test for gas by raising the candle gently from the floor. Long experience would enable him to tell when any gas was present, by the elongation of the candle flame. He then placed the candle in a shielded position, and proceeded to get rid of the gas by using his coat as a fan, testing the atmosphere from time to time with a candle as before. In those days ventilation was not what it is now, and if any explosion did occur it was confined to the working place where it occurred. A miner might be severely burnt and no one else in the mine might know anything

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about it. According to Acts of Parliament, however, that have passed to minimise the effects of gas, and of explosions, a large volume of air has to be circulated through the mine, a certain definite quantity being passed through each working place every minute. This has led to two results. In the first place, as the coal is worked, as successive quantities are broken away from the working face, the gas which is liberated is quickly diluted by the ventilating air current ; but when any gas is ignited in any portion of the mine, the ventilating air current carries the flame which is formed, with it, to every other portion of the mine on its way to the upcast shaft, and in so doing very often produces very disastrous results. Explosions in coal mines are now much less frequent, but they are very disastrous when they do occur. It is now known that coal dust plays a very important part in coal mine explosions. In the working of all coal mines, and particularly in some of the drier mines, coal dust is constantly formed. It lies in masses upon the roadways, upon the timbers employed to support the roof, and in every crevice that it can find. If this dust is raised in a cloud, and is ignited, it rapidly forms a gas, carbonic oxide, which itself possesses explosive properties ; the result being that from a comparatively small explosion in some remote part of a mine a very disastrous explosion may arise, and sometimes two or three explosions in different parts of the mine, owing to the raising of the cloud of coal dust and the formation of the explosive gas. The two shafts are known as the downcast and the upcast. The downcast is the one down which fresh air passes to the mine workings, and the upcast is the one up which the vitiated air from the mine escapes. From the bottoms of the two shafts, two roads, sometimes more than two, are driven out to the boundary of the area to be worked. One is called the "intake" and the other the "return." The "intake" is the main airway carrying fresh air to all the workings, and the "return" is the main airway gathering up all the vitiated air, and delivering it to the upcast shaft. All the workings, all the working places, the stables where horses are kept, and every place in the mine where men or animals can work and where gas may be given off, is con-

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nected between the "intake" airway and the "return" airway; and the ventilating air current is made to pass, by various devices, from the surface at the top of the downcast shaft, down into the mine through all the working places, and up the upcast pit. Fig. 38 shows diagrammatically the arrangement of the ventilation of a coal mine. The working coal face is shown, for simplicity, as a continuous irregular wall, along which the air current passes.

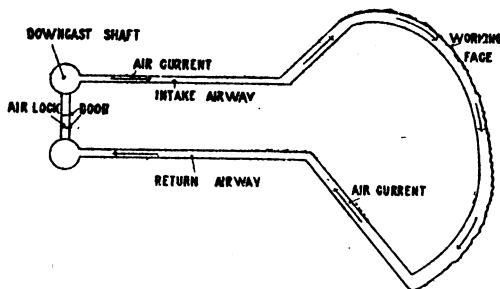


FIG. 38

Showing diagrammatically the arrangement of the ventilation of a coal mine; the air passing down the downcast pit, along the intake airway, round the working faces, and back to the surface by the upcast pit.

In actual mining work the working coal face is divided up into a number of districts, so that the haulage systems may be led to them conveniently, and for other practical reasons.

Plate XA shows a portion of a road in a coal mine in Northumberland, with the timber supports, and a screen of brattice cloth used to direct the air current. A "deputy," as he is called, is seen coming through the screen on his rounds.

METHODS OF WORKING THE COAL

There are three principal methods of working the coal, known as the "bord and pillar," "longwall," and the "panel" systems. There are other special methods for special conditions. In the United States of America also, a modification of the "bord and pillar" system is worked, that may be described as "pillar and stall."

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In the "bord and pillar" system, the portion of the seam to be worked, within the leased area, is divided up very much like the squares on a chess board. From the main roads described above, smaller roads are driven right and left at right angles to the main road, right to the boundary on each side, and again other roads of the same size are driven at right angles to these roads, parallel to the main "intake" and "return" roads, dividing up the coal in the manner described. The roads forming the lines of the chess board are usually about 8 feet wide; and it will be seen

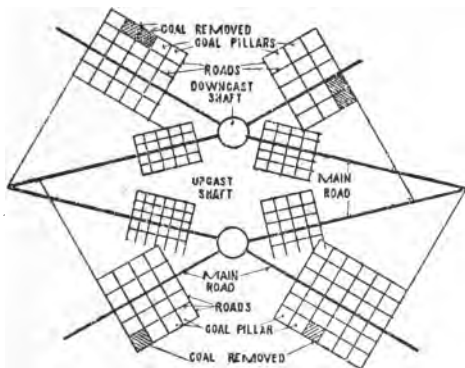


FIG. 39

Diagrammatic representation of the "bord and pillar" method of working the coal. For simplicity the roads, etc., connecting with the return and intake airways are omitted, on the respective sides, only one set of roads being shown.

from the diagram, Fig. 39, that they leave pillars between them corresponding to the squares of the chess board. It is necessary for the pillars to be left in order to support the roof. The roads are driven successively further and further away from the shaft, until the boundary of the lease is reached in all directions. Then what is called "working back" commences. When "working back," the pillars are removed, the roof being allowed to fall behind, as the working proceeds. "Bord and pillar" was the system employed in the North of England in the early days of coal mining, and when the seams to be worked were not at any

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great distance from the surface, and were of considerable thickness. With the working out of the shallower seams and the thicker ones, the "bord and pillar" method has been displaced by the "longwall" method.

In the "longwall" method of working, as its name implies, there is a long working face, varying from 100 yards or so to a mile or more, which is constantly moving forwards and generally increasing in length as the shafts are receded from. The method of arranging the longwall system varies. In Scotland there are usually a number of comparatively short faces of 100 yards or so in length, while in Yorkshire they may be from half a mile upwards. In any

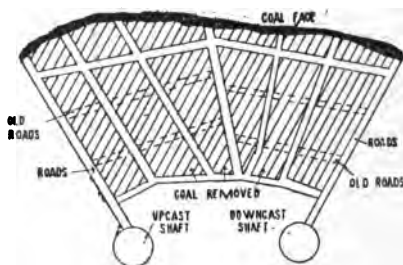


FIG. 40

Diagram illustrating the "longwall" method of working.

mine also there are usually several working faces, reached by roads branching off the main road.

The working face is not usually in an irregular line ; it is generally more in the nature of a curve, and where hand labour is entirely depended upon, a very irregular curve. Fig. 40 illustrates diagrammatically the "longwall" system of working.

In the "pillar and stall" system used in America, the roads employed in the "bord and pillar" system were extended to 20 feet in width when the system was first established, and latterly they have been extended to 60 feet. Each space of 20 feet or 60 feet wide forms a stall, and is separated from the next stall by a pillar of coal which may be 20 feet or more in width, according to the conditions of working (Fig. 41). This arrangement was adopted

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in America in order that machinery might be used in place of hand labour for what is called "holing," or "kirving," explained below. In America, labour has always been very scarce, and particularly the skilled labour required for "holing" the coal; hence machinery for performing the work was introduced at a very early stage of American coal mining.

The "panel" system may be considered as another modification of the "bord and pillar" system. The area to be worked is divided off into districts, or, as they are termed, "panels," each panel being divided from the rest by thick ribs of coal, which support the roof. The coal

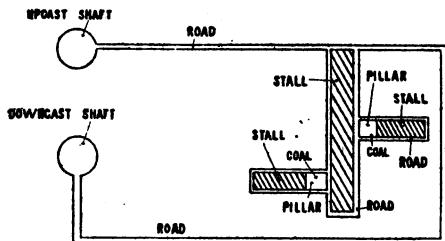


FIG. 41

Diagram illustrating the "pillar and stall" system of working employed in America.

inside of the panel is worked very much on the lines of the "bord and pillar" system. It is first divided up by small roads at right angles to each other, as in the "bord and pillar" system, leaving pillars, and the pillars are then removed. The thick coal of South Staffordshire, which is ten yards in thickness, is partly worked by a further modification of the "bord and pillar" system, and by an arrangement somewhat similar to the "panel" system. Rectangular chambers are worked out of the coal, divided from each other by thick ribs of coal, there being also pillars left in the centre of the chambers. It is rarely possible to get all the coal in the very thick seams; a good deal has to be left behind to support the roof, and a good deal cannot be obtained for practical reasons.

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SUPPORTING THE ROOF IN THE "LONGWALL" SYSTEM

In all the other systems of working the roof is supported

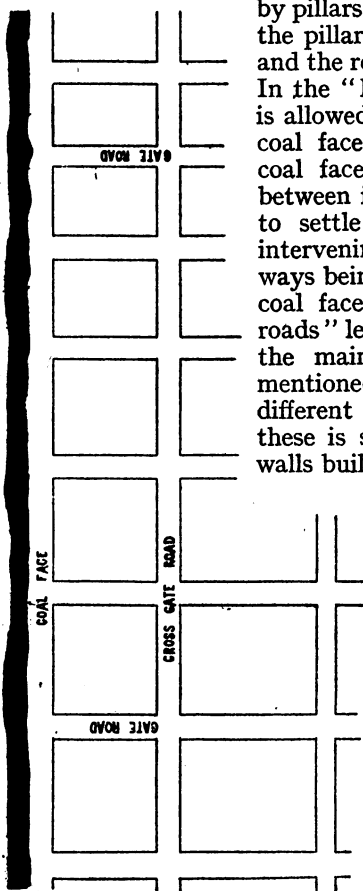


FIG. 42

Showing diagrammatically the arrangement of gate roads and cross gates employed in "long-wall" working.

by pillars of coal left for the purpose, the pillars being withdrawn later on, and the roof allowed to come down. In the "longwall" system the roof is allowed to fall behind the moving coal face. That is to say, as the coal face moves forward, the roof between it and the shafts is allowed to settle down and close up the intervening space, subject to roadways being kept open leading to the coal face. What are called "gate roads" lead from the haulage roads, the main roads that have been mentioned, to the working face at different intervals; and the roof in these is supported, partly by pack walls built of the stone that is found

in the mine, and partly by timber. As the face moves forward, the gate roads behind are cut off by what is called a cross gate, the roof being allowed to come down in the previous roads. From the face of the coal, the gate roads, in which tram rails are led, lead to the cross gates, and these are in connection with the main or secondary haulage roads. Fig. 42 shows diagrammatically the arrangement of gate roads and cross gates. For supporting the roof at

Coal Mining

the working face, lines of timber are employed, as shown in Fig. 43, the timber being withdrawn as the face moves forward. There are certain difficulties in working very thick seams and very thin ones. With very thick seams the difficulty lies in getting all the coal; in very thin seams the difficulty arises in working, because the space between the strata is so small. The most comfortable

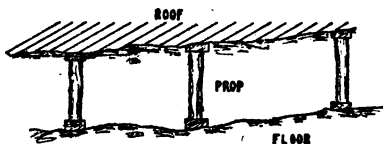


FIG. 43

Showing how props are employed to support the roof.

thickness for a coal seam is about 6 feet. Roads driven in a coal seam of that thickness are of a comfortable size, and if the roof is good the working is comparatively easy. Seams of 4 feet work fairly easily, but not as comfortably as those of 6 feet. Seams as thin as 18 inches are worked, and in some cases without either making head room, by removing the rock above, or removing the floor. The conditions under which work has to be carried on in these seams render the working very expensive.

CHAPTER VII

GETTING THE COAL

IT has been explained in previous chapters that the coal lies between other strata, just as the ham lies between the two slices of bread in a sandwich. In order that the coal shall be removed from its bed, space must be provided for it to do so ; and this is usually accomplished by "holing," or "kirving," as it is called in the North of England, under the coal. By "holing" or "kirving" is meant cutting a groove between the body of the coal and the strata on which it rests, of sufficient depth and sufficient width from front to back to allow the coal to fall down. With hand holing the miner cuts the coal away in an irregular form. It has to be undercut as far back from the face as the next movement of the coal face requires. Thus, if the face moves forward 3 feet, the undercut must be 3 feet wide from front to back ; if 4 feet of coal is taken, the undercut must be 4 feet wide; and so on. To accomplish this the working miner has to lie on his side, partly under the coal, and chip it away with his pick. In very thin seams it was often very difficult indeed for him to turn round from one side to the other. There are tales of men having to be pulled out by the feet in order to enable them to turn round and work on the other side. It must be remembered also that the miner was working only by the aid of a lamp giving considerably less than a candle-power.

In some cases there is what is called a "dirt parting" between two portions of the seam ; and where this occurs, the "holing" is done in the "dirt parting." It also sometimes happens that the strata above the coal is of a somewhat similar nature, and can easily be removed, and in that case the "holing" is done above the coal.

Getting the Coal

THE COAL-CUTTING MACHINE

The coal-cutting machine has been designed to perform the work of hand holing, mainly at less cost than the miner can accomplish it, and with a greater speed. The miner, the man who undercuts the coal, is paid a piece-work rate, so much for each ton that he undercuts, the coal he sends up being weighed on the surface, and credited to him. As all piece-work wages are based upon day-work wages—that is to say, a man receives a rate per piece that will enable him when working normally to earn the amount he would command if paid by the day—it will be seen that the longer it takes the working miner to undercut a ton of coal, and the thinner the seam he undercuts, the heavier is the cost of undercutting. In one case which came under the writer's notice, a seam of coal in Yorkshire was so thin, and the cost of holing by hand was so great, that it could not be put upon the market until a machine was employed for the purpose.

There are broadly five types of coal-cutting machines upon the market: the machine which the Americans call the "coal puncher," the "disc" machine, the "bar" machine, the "chain" machine, and the "heading" machine.

The "coal puncher" is practically a development of the rock drill, but it is very much larger and more powerful. It may be described also as a cannon worked by compressed air, and driving a coal-punching tool in place of a shot. It consists of a cylinder in which a piston moves to and fro, driven by compressed air. To the front of the piston is attached a rod which carries the coal-punching tool, something in the nature of a drill. The whole apparatus is mounted on wheels, and the machine-man sits behind, governing the work of the machine by means of two handles, and keeping it up to the face by chocks of wood which are attached to his boots and are held against the back of the wheels. American miners seem to have taken very much to this machine, and to like it; but English miners do not like it at all; they say that it shakes them too much. The American miners reply that the Englishmen do not know

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how to work the machine, that they should not receive the shock of the machine on recoil. The "coal puncher" cuts a groove in the coal very similar to that which the miner cuts. It does the work very much quicker than by hand, and at less cost.

In the "disc" machine, as its name implies, there is a large ring or disc, ranging from 3 feet to 6 feet in diameter, carrying cutting tools at its edge. The disc is made to revolve, either by compressed air or by an electric motor, and as it revolves the cutting tools scrape away the coal or underlying clay.

It cuts a groove about 4 inches deep vertically, and as wide as may be desired. In some of the Yorkshire mines undercutting to the extent of 7 feet has been obtained, while 6 feet is quite common. In Scottish collieries 3 feet is the more usual figure. Fig. 44 shows diagrammatically one form of a "disc" coal-cutting machine.

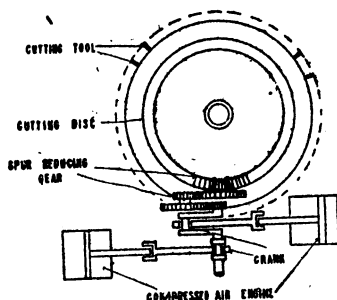


FIG. 44

Showing diagrammatically the working of one form of disc coal-cutting machine. The disc carries cutting tools at its edge, and is revolved by power furnished by the two compressed air engines shown; the speed being reduced by means of the gear wheels shown. The other parts of the machine are omitted for the sake of simplicity.

There are many forms of it. The disc is held by a framework, which also carries the compressed air engine, and a small drum on which a small wire rope is coiled. The wire rope is taken out in front of the machine and attached to a

prop, and as the machine cuts it also hauls itself along the face. The frame of the machine is sometimes mounted on small wheels, which run on rails similar to those employed for the colliery wagons, and which have to be laid in front of it as the cut proceeds; it is sometimes run on skids, similar to those of a sleigh, and sometimes upon wheels without flanges, which run upon the ground. The "disc" coal-cutting machine was the first to be successful, in this country at any rate, because it could be depended upon to cut through anything that was met with. On the

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other hand, it takes a great deal of power, and does not render itself so readily to working with the three-phase alternating electric currents that are now so commonly employed in mines.

It presents a large surface when the coal settles down upon the disc, as it sometimes does, and then it requires a considerable amount of power to work it. On the other hand, apparently there are no conditions so bad that the disc machine will not work through them, provided power is available.

The disc machine is sometimes worked with one engine, or one electric motor, and sometimes with two, as shown in Fig. 44. In the latter form of machine the engines and the electric motors are placed at each end of the frame of the machine, both gearing into the disc, which is placed between them. Plate XII shows one form of disc machine.

THE BAR MACHINE

In the bar machine, as the name implies, there is a bar, which is sometimes cylindrical, the same size throughout its length, and sometimes tapered towards the inner end. The bar carries a number of small cutting tools, small editions of the end of the miner's pick, which are held in holes in the bar. The bar is made to revolve, and as it does so the picks strike against the coal, or whatever the machine may be cutting in, and chip it away. There is a small haulage drum attached to the end of the machine, on which a small wire rope is coiled, as with the disc machine, the machine pulling itself along the face of the coal as the cut proceeds. In addition, in the modern bar machine the bar is arranged to swivel right round from a position in line with the body of the machine, to a position as nearly in line with it at the other end as it is possible for it to go. When undercutting the coal the bar stands out at right angles to the body of the machine, and it is made to cut its way into the coal, from the position in line with the machine. The modern bar machine is made to cut in both directions; that is to say, the machine is run along the face of the coal, the bar turning in one direction as the cut proceeds; and

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when the coal which has been undercut is filled out, the machine is taken up to the new face, and cuts its way in and back across the face to the opposite end, the bar turning in the opposite direction. A plate of iron is sometimes ar-

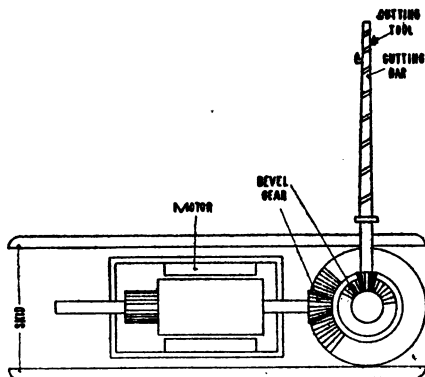


FIG. 45

Showing diagrammatically the working of one form of bar coal-cutting machine driven by an electric motor. The power is delivered to the bar through the gear wheels shown, some of which are also employed in turning it round when cutting its way into the coal. The machine is shown mounted on skids. Many details are omitted for simplicity.

ranged to follow the bar machine, to bring out the fine dust and chips that are made in the process of cutting. Fig. 45 shows diagrammatically the working of one form of the bar machine.

THE CHAIN MACHINE

In the chain machine, the working of one form of which is shown in Fig. 46, the cutting tools are carried by a chain, but the chain is protected by a jib, as shown in the figure, consisting of two metal plates, held apart by bolts, upon which rollers revolve, the chain passing around the rollers. The jib is made to revolve through an angle, from a position in line with the body of the machine, right round to as nearly as it can get in the opposite direction, and the cutting tools on the chain are made to cut their way into the coal,

Getting the Coal

as with the bar machine. The working of the chain machine is similar to that of the disc machine, except that

the chain is protected from the effect of a squeeze by the pressure of the coal, and the chain only moves and not the whole arrangement as in the case of the disc. The chain machine is not considered suitable for as heavy work as the disc, though it is steadily making its way. It is hauled along the face as the cut proceeds by a small haulage rope,

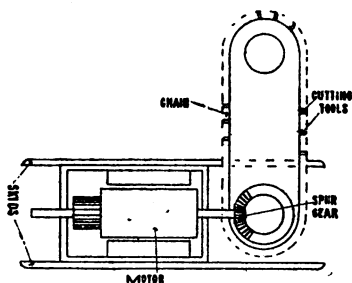


FIG. 46

Showing diagrammatically the working of one form of the chain coal-cutting machine for longwall working.

in the same manner as the disc and bar machines. Fig. 47 shows a longwall coal-cutting machine working along a coal face. The haulage rope will be noted in front.

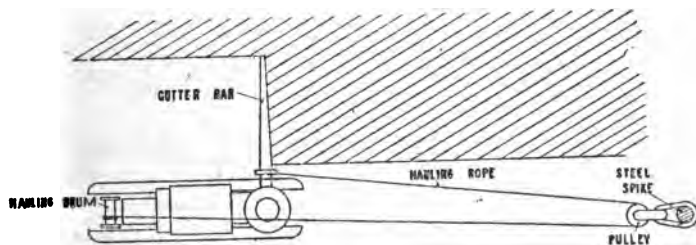


FIG. 47

Diagram showing a working coal face with a coal-cutting machine moving along it.

THE CHAIN HEADING MACHINE

In the chain heading machine, one form of which is shown in Fig. 48, there is a framework, nearly rectangular, carrying rollers, upon which the chain moves when the machine is at work, the chain carrying cutting tools as with the longwall machine. The framework, with the chain and cutting tools, is carried upon the body of the machine

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which again rests upon rollers, or skids, and sometimes upon flanged wheels. The chain heading machine is designed to make a series of narrow cuts, usually 2 feet 8 inches wide, under the coal, in narrow places that are being opened out, such as what are called headings, and the roads in bord and pillar working. Three cuts, each 2 feet 8 inches wide, make up the 8 feet of road in the bord and pillar system. It is

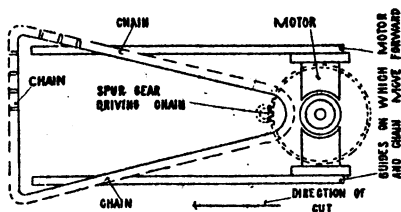


FIG. 48

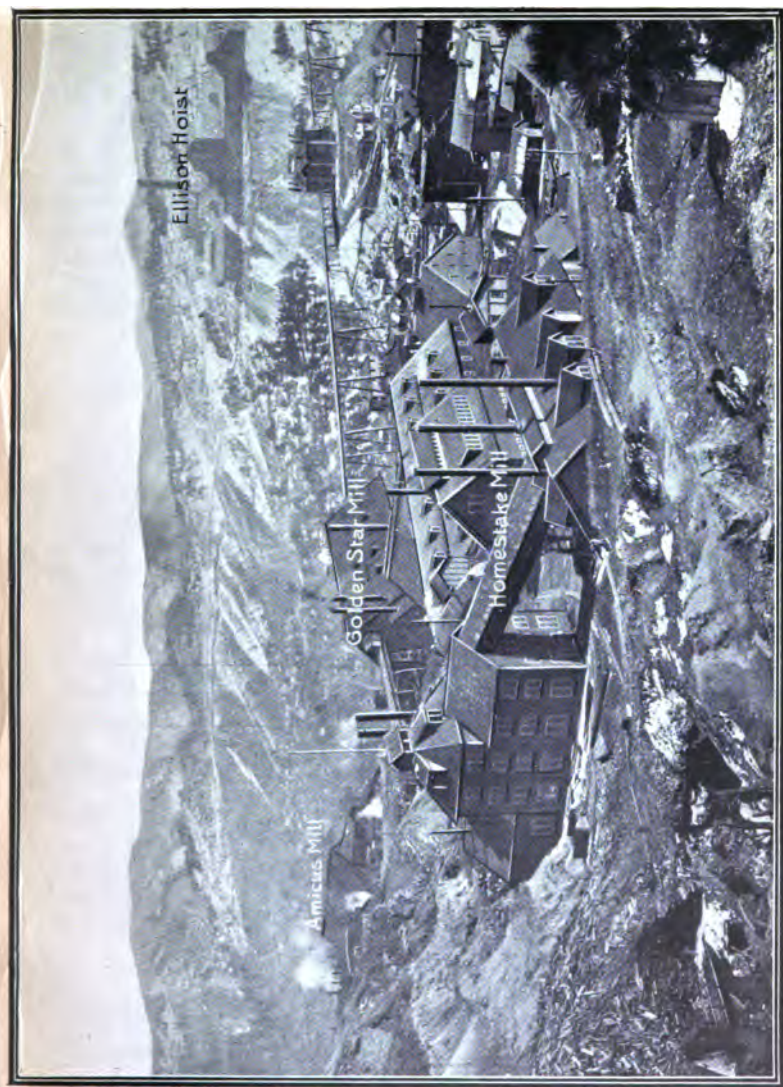
Diagram showing the working of a chain heading machine

this machine which is so largely used in the American "pillar and stall" working. It is first brought up close to the face of the coal, on one side of the stall, or on one side of the heading that is to be driven, and there wedged in position by chocks between the

roof and the machine at each end. The movable framework carrying the chain is then run forward up to the face of the coal, and the chain and the cutting tools are made to run round the framework, the tools cutting their way into the coal. The framework carrying the chain is pushed steadily forwards as the cutting proceeds, until the cut is of the width required: 3 feet, 4 feet, or more, from front to back. When the cut has proceeded to the width required the framework is run back, and the whole machine is moved bodily 2 feet 8 inches away from the space it has recently occupied; it is again wedged, and a fresh cut made, the machine being again moved, and so on.

The chain header is worked by compressed air, and by or electric motors. In both cases the power from the engine the motor causes the chain to move round the framework; it causes the framework to move outwards and backwards, and it furnishes the power enabling the cutting tools to cut away the coal. The power also is employed in moving the whole machine to its next position.

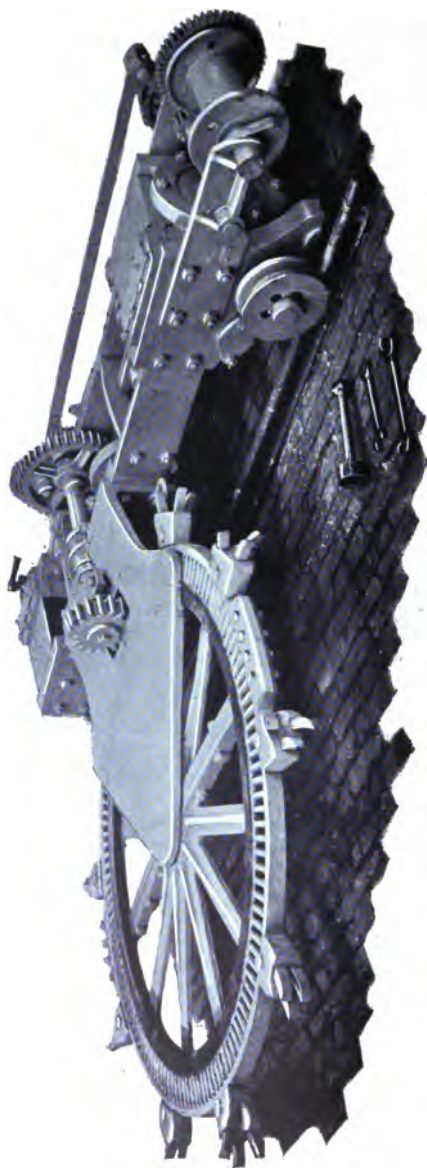
The disc machine, the bar machine, and the jib chain machine, are all used in longwall working; the chain



GENERAL VIEW OF A MINING PLANT ON THE SURFACE

PLATE XI

To face page 96



DOUBLE CYLINDER AIR-DRIVEN DIAMOND DISC COAL-CUTTING MACHINE

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PLATE XII

Getting the Coal

headers are used in driving headings, as when the mine is being opened out, driving fresh roads in fact, and in "bord and pillar" and similar work.

THE RADIAL COAL-CUTTING MACHINE

There is another form of coal-cutting machine that has gradually come into use during the last fifteen years: an adaptation of the rock drill. It is really a rock drill having the body of the machine supported by a pillar, wedged between the roof and the floor in such a manner that the drill which is attached can sweep through any angle: vertical, horizontal, or any angle between them. It is also arranged for the drill to have different lengths of cutting tools. In practice the machine is set up at a certain distance from the working face; a radial cut is made horizontally to a certain depth; then a longer tool is put into the machine, a further cut is made to a greater depth, and so on, until the required depth of cut is obtained. The machine is then moved up a certain distance, and the process repeated. This machine is of great use in "bord and pillar" work for what is called "nicking." It will be understood that in longwall working, with a long face of coal undercut, the weight of the coal itself tends to overcome the cohesion between itself and the strata above, so that it comes down with comparative ease. Where the working face is very short, as in the case of headings that are being driven a few feet in width, or in "bord and pillar" work, the weight of the coal to come down exercises very little effect, and therefore it is usual to make a cut, called a "nick," at one or both sides to help the coal to break away.

In all cases of undercutting the coal, it is kept in place until the time when it is required to come down, by short pieces of wood, chocks, or props. It is one of the arts of the miner to successfully prop up the coal until the proper time. With hand holing, his own life very often depends upon his skill in the matter.

With coal-cutting machines, one of the difficulties arising is the removal of the dust that is produced in the working of the machine. The cutting process varies with the differ-

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ent machines, but there is always a considerable amount of dust, and in any case the chips, or whatever is made, require to be moved from the groove that is cut, or if the coal settles down again upon it the cutting would have to be done over again.

The cut made with the coal-cutting machine is usually only about 4 inches in depth, from the floor to the coal, while the cut made by hand holing has to be of a sufficient height for a man to get his shoulders under.

Hand holing is generally done in the coal itself, but when machines are employed they are often worked in the clay which usually underlies the coal, the object being to get a larger proportion of round or large coal. Cutting in the coal itself breaks it up into small, which has a lower value than large coal. On the other hand, the development of the mechanical stoker has rather changed the conditions of coal mining. With the mechanical stoker, small coal can be used in boiler furnaces quite as well as large coal, and hence the value of small steam coal is now within a few shillings of that of large coal. It is complained, on the other hand, that when the coal is broken down, after undercutting by machine, it does not break up into lumps that can be conveniently handled, and filled into the mine wagons; so that a certain amount of labour is required to break it up, or additional shots have to be fired in it for the same purpose.

DRILLING AND BLASTING

In some cases, with some seams, the cohesion between the coal and the strata above is so small, and the cohesion between what are called the "slips" of the coal, the natural cleavages, usually at right angles to the strata, is also so small, that the coal comes away without any help. In one particular colliery in Yorkshire, where the coal was undercut to a width of 6 feet, the seam being 6 feet in height, no assistance of any kind was necessary. In the great majority of cases, however, the coal has to be assisted by blasting, on somewhat similar lines to those described with metalliferous mines. Where the undercutting is at the bottom of the seam, holes for blasting are drilled a little way from the top

Getting the Coal

of the seam, to the same depth as the undercutting has been carried, and a charge of explosives is placed right in the bottom of the hole; the hole is filled up by tamping, just as in the case of metalliferous mines, and a number of holes are fired together, either by safety fuses or by electricity. Fig. 49 shows a section of a coal seam which has been undercut by a machine, and showing the groove made; also the shot hole with charge and fuse. The fuses employed in coal mining are exactly the same as those employed in metalliferous mining, including the miner's squib, the safety fuse, and the high and low tension electric fuse.

Drilling may be carried out by hand or by machine. The machine drill sometimes worked by compressed air, but latterly more frequently by electricity, is steadily displacing the hand drill. When the shots are fired the coal is broken up to a certain extent, and broken away from its surroundings. It is then filled into the mine wagons that transport it to the surface.

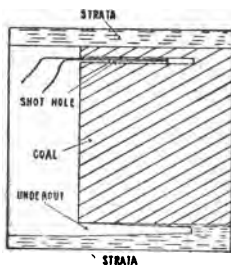


FIG. 49

Diagram showing the groove made by a coal-cutting machine under the coal, and a shot hole with a charge of explosive and fuse, etc., above.

THE COAL CONVEYOR

Quite a modern development of the last ten years or so is the coal conveyor for the face of the coal. In very thin seams, the labour of carrying the coal from the face to the gate end roads, where the mine wagons are, is somewhat arduous, and the time taken is long. To meet this a portable coal conveyor has been worked out, consisting of a number of troughs about 6 feet long, which are placed along the face of the coal, end to end, in succession. Inside of the troughs there is a conveyor of a special type, consisting of a chain with long links, and with attachments, projections which catch the coal that is placed in the conveyor, and carry it along to the end of the face, where the mine wagon is waiting in the gate end road. With the conveyors, all the men have to do is to lift the coal on to the conveyor, the

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apparatus does the rest. The conveyor is kept continually working, either by an electric motor or a compressed air engine, placed at one end. Fig. 50 shows one form of the conveyor.

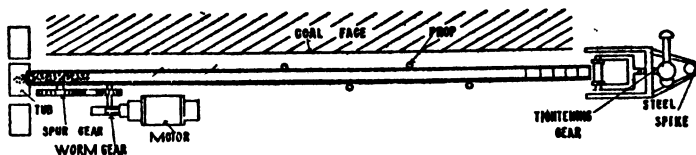


FIG. 50

Diagram showing the working of a coal conveyor at the coal face.

CHAPTER VIII

GETTING THE COAL TO THE SURFACE

THE MINE WAGON

THE wagons, or hutches, as they are sometimes called, or trams again as they are also sometimes called, vary in size and in construction. In some districts they are made to hold only about 12 cwt. each, while in South Wales they are made to hold as much as 30 cwts. The differences in the sizes of the wagons are due to the difference in the thickness of the seams and the conditions of working. In South Wales the mine roads are large and wide, the coal seams being usually thick, while in other parts, such as Lancashire and some parts of Yorkshire, the seams are very thin, and the mine wagons are proportionately small. In the early days of mining the coal was carried in sacks upon the shoulders of men and women; and when mine haulage was adopted, the mine wagons were constructed for a long time of wood. Fig. 51 shows one form of wooden wagon. Steel has only gradually displaced wood. At first the frame of the wagon was of steel, and the sides and bottom of wood; gradually the wagon has been made entirely of steel. In nearly all cases it runs upon small flanged wheels, upon small rails specially made for the purpose, and laid upon the mine floor to a very small gauge. For a long time also the sleepers upon which the mine rails were laid were of wood, with the usual iron

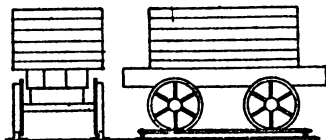


FIG. 51
One form of wooden mine wagon.

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chairs for the rails to rest in. To a large extent steel sleepers, with the chair for the rail to rest in punched in them, have taken the place of wood sleepers. The friction of the mine wagons upon the rails, and of their wheels upon their own axles, is often very considerable.

METHODS OF HAULING MINE WAGONS

There are two distinct parts in mine haulage to be considered: the haulage of each individual wagon from the working place where it is filled, to the haulage road, and the haulage from thence to the pit bottom. In the early days of mine haulage, the whole of the work was done by horses. Occasionally donkeys were to be seen in coal mines, because their small height enabled them to work in comparatively low places. The horse was first displaced for the main haulage roads, those which convey the coal out to the bottom of the shaft. For a long time after mechanical haulage was adopted for the main roads, horses, or ponies as they are sometimes called, were employed for hauling the mine wagons from the working faces to the main roads. Now the horse, the pony, and the donkey are steadily being displaced by mechanical haulage, right away to the face of the coal. The development of the use of electricity in mines has enabled what is called secondary haulage, that which feeds the main haulage, to be worked more and more by power.

The arrangement may be taken to be as follows: In the "longwall" system of working, in the "bord and pillar" system, and in the "panel" system, branch roads lead from the main haulage roads into the different working places, and small haulage ropes pass down these roads and haul the individual loaded wagons along from the face to the main haulage road. The empty wagons which are returning from the shaft bottom are usually pushed along the gate roads to the face by manual labour, the haulage ropes being carried out with the wagon as it is pushed along. The labour involved in pushing an empty wagon along is not serious, and men must be always at hand when either horses are pulling full wagons or mechanical haulage is

Getting Coal to the Surface

performing the work, to see that the wagon wheels do not get off the rails.

In the main haulage roads there are two principal systems of working, what is known as the "main and tail" system, and the "endless rope" system. In the "main and tail" system, a number of wagons are brought to some part of the main haulage road, and are connected together to form a train. At some convenient point in the neighbourhood of the shaft bottom a pair of drums are fixed, arranged to revolve in either direction by the aid of power. One drum carries what is called the "main," and the other what is called the "tail" rope. The "main" rope is run out and is attached to the front of the train of wagons; and the "tail" rope is run out to a point beyond the rear of the train of wagons, taken round a pulley at that point, and is attached to the rear wagon of the train. When all is ready, the drum carrying the main rope is revolved so as to wind it up, and that carrying the tail rope so as to unwind. When the train of wagons reaches the neighbourhood of the engine house the ropes are disconnected, and either horses or manual labour, or some auxiliary haulage, sometimes an incline, carries the full wagons to the shaft bottom. A train of empty wagons is then made up and connected to the main and tail ropes. The tail rope is attached to the front of the train, and the main rope to the rear. The tail rope drum is revolved so as to wind its rope up, and the main rope to let its rope out. In this way the train of empty wagons is hauled out to the point where the full wagons were drawn from, where it is

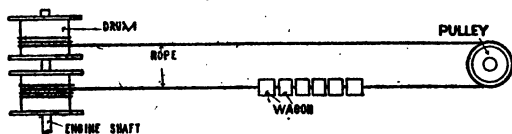


FIG. 52

Diagram showing the working of the "main and tail" system of haulage.

distributed to the working faces; and the main and tail ropes are ready to haul out a train of full wagons. The great advantage of the "main and tail" system is, it only

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requires a road sufficiently wide for one line of rails. On the other hand, the engine power has to be very much greater, at least five times that of the power required for "endless rope." The actual power in horse-power hours consumed does not vary in this proportion, because the "main and tail" engine is only working for a short time at intervals, while the "endless rope" engine is working the whole of the time. Fig. 52 shows diagrammatically the main and tail system.

In the "endless rope" system there are two lines of rails, one for the full wagons, which are being hauled out to the shaft bottom, and the other for the empty wagons which are being hauled back to the working faces. The haulage rope is arranged to be fed from branch roads leading to the working faces; secondary haulage drawing the individual wagons up the branch roads to the different points where the wagons are to be attached to the haulage ropes. There is a continual stream of full wagons coming out from the working faces to the shaft bottom, and a continual stream of empty wagons being drawn out to the working faces. The full wagons are attached to the rope that is travelling towards the shaft bottom, and the empty wagons are attached to the rope that is travelling outwards to the working faces. As the name implies, there is one rope passing from the haulage engine right out to the farthest working place, where it passes round a pulley, and comes back, usually round another pulley, to the haulage engine.

Motion is given to the rope by what are termed friction pulleys, usually two pulleys, one in front of the other, on

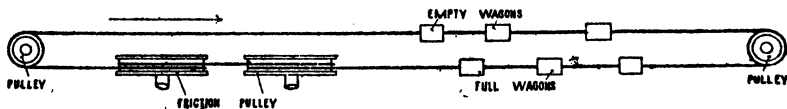


FIG. 53

Diagram showing the working of the "endless rope" system of haulage.

each of which the rope is given three turns. Other forms of friction pulleys have been introduced from time to time, but they have practically given way to the one form,

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Fig. 53 shows diagrammatically the working of the endless rope system.

In mines covering large areas there may be several main and tail ropes, working from an engine in some convenient spot near the pit bottom to the different districts, and there may also be more than one endless rope system.

Previous to the introduction of the endless rope system, endless chains were used in Lancashire for the same purpose, and there are some at work to-day. The endless chain system is somewhat simpler than the endless rope system, because of the ease with which attachments are made between the chain and the wagon, as compared with ropes. With the endless chain system a fork was carried on each end of the mine wagon, into which a link of the chain fell, and when the wagon arrived at its destination the chain automatically lifted out of the fork. Something similar has been attempted with the endless rope; but special forms of clips are more frequently used, which are attached to the rope by men at the hitching stations, and detached when the wagons are to be taken off the ropes.

DIP HAULAGE

The dip haulage is one form of secondary haulage. It consists of a single drum arranged for a rope to be coiled up on it, or for the rope to be uncoiled, and it is placed at the tops of inclines. Sometimes empty wagons are let down the incline to the face, full wagons being pulled up by power; and sometimes the incline is made self-acting, full wagons running down it and pulling the empty wagons up.

METHODS OF DRIVING HAULAGE PLANT

When mechanical haulage was first introduced steam was the only power available, and steam engines were connected to the drums by gearing. There were great objections to the use of steam underground. Either steam had to be generated in boilers underground, or to be carried down the shaft. In the early days of mining boilers were fixed underground, but they have gradually been displaced. There was always the danger of fire, and in some cases it

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was very difficult for men to work for more than a few hours at a spell owing to the heat. Where steam was carried down the shaft the loss by condensation in the steam pipes was very great. Also where the steam was generated in boilers at the shaft bottom the loss by condensation of steam in the pipes leading to the engines driving the haulage plant was also very great. In "bord and pillar" mines the distance of the haulage engine from the shaft bottom was sometimes fairly considerable. By condensation of steam in the steam pipes is meant the return of the steam to the liquid state, owing to the loss of heat by radiation and other causes, in the steam pipes, during the passage of the steam to the engine.

Compressed air was the next agent employed for driving haulage plant. Ordinary atmospheric air is compressed on the surface to varying pressures: in the early days up to about 30 lbs. per square inch; in these days up to about 100 lbs. per square inch. The compressed air was carried down the shaft and along the roads to the engines to be driven, and was there allowed to expand in the engine cylinders, driving the pistons in a manner similar to steam. There were, again, great objections to the use of compressed air. There were very heavy losses of power. In compressing the air on the surface it was heated to a temperature depending upon the pressure, this heat representing the power expended in compressing the air. The power expended in the heat was lost, and there was also a considerable amount of loss through leakage in the pipes on the way to the haulage engine. When the air expanded in performing its work at the haulage engine, in the process of expansion it cooled itself and surrounding objects to so great an extent, that if any moisture was present in the air, as in the early days there always was, ice was formed in the exhaust parts of the engine and reduced the power available. A good many of these difficulties have gradually been overcome. The air is drained of moisture before it is allowed to reach the engine, and it now works very much more efficiently than in the early days. In America small locomotives are employed in some of the mines working by compressed air, a reservoir of which is carried on the loco. Some thirty

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years ago compressed air locos of a similar kind were used in the Earl of Durham's, now Lord Joicey's, mines in the county of Durham.

A system that was first adopted in Germany also meets the case very fairly. The air compressor is now placed underground, as nearly as possible to the engine it is to work. The arrangement is intended principally for working coal-cutting machines and drills. The air compressor is worked by an electric motor, the air being used in the same manner as when it is compressed on the surface.

Wire ropes competed for a long time with compressed air, and were very successful, and there are still a number of wire rope installations throughout the country doing good service. With wire rope transmission of power, an engine fixed on the surface causes a friction pulley to revolve continually, the friction pulley being similar to that described for endless rope haulage. The transmission wire rope is also endless. The two parts of the rope, the one going forward and the other returning, work in the shaft at a sufficient distance from each other to avoid the danger of their getting in each other's way ; they are carried round pulleys at the shaft bottom, where sometimes the loop ends, power being taken from an axle which the shaft rope causes to revolve, to drive another endless rope, furnishing power to other pulleys, working pumps, or haulage systems, and in one case a coal-cutting machine, at different parts of the mine.

The wire rope transmission system was very efficient, in the sense that it wasted very little power, while if the ropes were properly arranged the wear was not great. They are steadily giving way, however, to the electric drive, which is displacing everything on account of its great convenience.

THE ELECTRIC DRIVE

The electric drive has gradually made its way, because of the great convenience with which the distribution can be carried out. At the present time an electrical power generating station is fixed at some convenient place on the surface in the neighbourhood of the mine, where there is a

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supply of water, and where it is convenient to deliver coal for the boilers, and from this point cables carrying high-pressure electric currents are carried to all parts of the mine, and often to several mines of a group. Cables are carried down the shaft, for instance, and are led to electric motors that are arranged to drive each haulage plant, each pump, etc. The efficiency of the electrical system of distribution is very much higher than that of either compressed air or steam—that is to say, there is a very much smaller waste of power; the proportion between the power actually delivered to the haulage drums, the pumps, etc., and that required on the surface, is very much more favourable with the electric drive than with any of the others, except rope transmission. There are, again, objections to the electric drive. It is unfortunately dangerous in two ways. A great many men have been killed by receiving shocks from exposed portions of the distribution system, and fires have been caused by arcs set up between portions of broken cables. Plate XIII is a view of an electrically driven endless rope haulage.

In America and on the Continent electricity is used in coal mines in a form which so far has not been adopted in this country. The electric mining locomotive is a very common feature in America and on the Continent. It is only used in one case in this country, at a lead mine in Cumberland. The arrangement for its use is similar to that described for the haulage of skips in metalliferous mines. The electric loco runs on the tram rails, its own flanged wheels being arranged for the purpose. There is an overhead copper wire carried along the whole of the roads where the electric locos are to run, and a small trolley pole with a wheel at the end makes connection with the controller upon the loco, which is similar to the controller of the ordinary town electric tram, the current returning by way of the rails. There is a seat upon the loco for the driver, who has complete control of the apparatus, can run to and fro as required. In the "pillar and stall" system, described in connection with American mining, electric locos run into each "room" and draw out the filled trams, making them into a train, which is either hauled to the shaft

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bottom by a haulage rope or by an electric loco. Plate XIV shows an electric trolley loco in use in a German mine.

The objection to the use of the electric loco is the danger of sparking between the wheel at the end of the trolley and the trolley wire ; and also between the flanged wheels of the loco and the rails upon which the loco runs. If gas is present, a spark between the trolley wheel and the trolley wire would ignite it at any moment, and gas, if present, always rises to the roof. There is also the danger, and a somewhat serious one, of a trolley wire being broken, falling on the rails, forming an arc between itself and the rails, and igniting the coal dust that is always present there. There is the further danger, and again a serious one, of miners receiving shocks, both by accidentally touching the trolley wire and from connections being made between the trolley wire and some other metals about the mine, such as haulage ropes, pulleys, etc.

There is a tale from America of a vicious mule which received a fatal shock by biting the trolley wire when it was standing between the rails, its hoofs being covered with water and coal dust. Another form of electric loco, in which the current is furnished by a battery of accumulators, has been used to a small extent in America and on the continent of Europe.

In the electrical distribution systems in coal mines in the United Kingdom there have been many serious cases of shock, owing to the distribution conductors making contact with metal bodies about the mine, such as ropes or pulleys, which again have made connection with other metallic bodies, such as the frames of mine wagons, and men have received shocks from one of the metals that should have been perfectly innocent.

RAISING THE COAL TO THE SURFACE

All coal mine shafts are vertical, and there are now always two cages, one of which, when the engine is not running, is at the shaft bottom, and the other at the shaft top. This applies to each shaft. As there are two shafts now to every coal mine, there will be four cages working : two conveying

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coal from the bottom to the top, and two conveying empty wagons from the top to the bottom, except when men are being let down or drawn out. Nothing is allowed to be on either cage when men are riding, except men. The cages are made to carry from two mine wagons up to as many as six. They are sometimes what are called single deck ; that is to say, they have one platform upon which the wagons are held ; they sometimes have two decks, two platforms one above the other, and occasionally there are three decks. Also in some cages two wagons will be held upon each deck ; in other cases four, and occasionally more. It is of great importance to raise as much coal at each wind as possible, hence the arrangement for carrying as many wagons as possible. Where there is more than one deck to the cage there are two platforms at the shaft bottom, from which the cage is loaded. The usual plan is, the full wagons are pushed on to the cage, the catches which hold the empty wagons having been removed, and the empty wagons are pushed off, and are run away to the haulage system which carries them to the coal face. At the pit top there are also sometimes two loading decks ; but more frequently one deck is unloaded, empty wagons being pushed on while the full wagons are run off, the cage being then lifted for the other deck to be unloaded and reloaded. Various methods are in use for aiding the unloading and reloading of the cages, both at the shaft top and shaft bottom, hydraulic power being a favourite. Plate XV is a view of the shaft bottom of one of the new collieries being opened in Kent.

The cages are attached to the ends of two wire ropes, which pass over pulleys on the head stocks above the mine, and thence to the winding drums. There are two winding drums, arranged to be revolved in opposite directions. One drum revolves so as to wind up its rope, hoisting the cage from the bottom to the surface, and at the same time the other drum revolves so as to unwind its rope, allowing the cage that was on the surface to be lowered to the bottom. Fig. 54 shows diagrammatically the arrangement of a pair of winding drums, with the ropes and cages.

The usual method of driving the winding drums is by

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two steam cylinders, the axles of the drums being connected mechanically to the crank shaft of the engine.

The steam winding engine is a very wasteful apparatus. It consumes a very large quantity of steam, and hence the electric winder is being introduced to take its place.

In the electric winder the drum is driven by an electric motor, geared to the axle, and furnished with current in accordance with the work it has to do. The mechanical problem involved in winding is a somewhat difficult one. When the cage is first lifted from the bottom a very large quantity of power is required, and for a few seconds after the power goes on increasing. Then the power required steadily decreases to nothing, and for the last portion of the wind power is being delivered to the winding drum, if advantage can be taken of it. In the electric winding apparatus, by the aid of a fly-wheel and special arrangements, the energy delivered during the later portion of the wind is stored in the fly-wheel, and goes to assist at the commencement of the next wind. This arrangement also protects the electrical distribution system from the effects of the very heavy demand for current that would be made if the motors took their current directly from the distribution service.

Notwithstanding this, however, in Germany and in America there are several cases where the winding drums are worked by electric motors, taking their current directly from the distribution service.

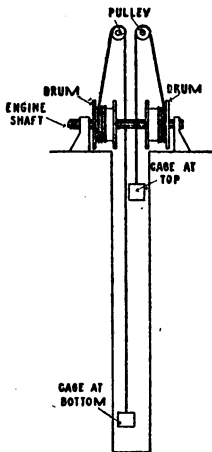


FIG. 54

Diagrammatic sketch showing the arrangement of the winding drums, ropes, and cages at a colliery, one cage being at the shaft bottom, and the other at the top.

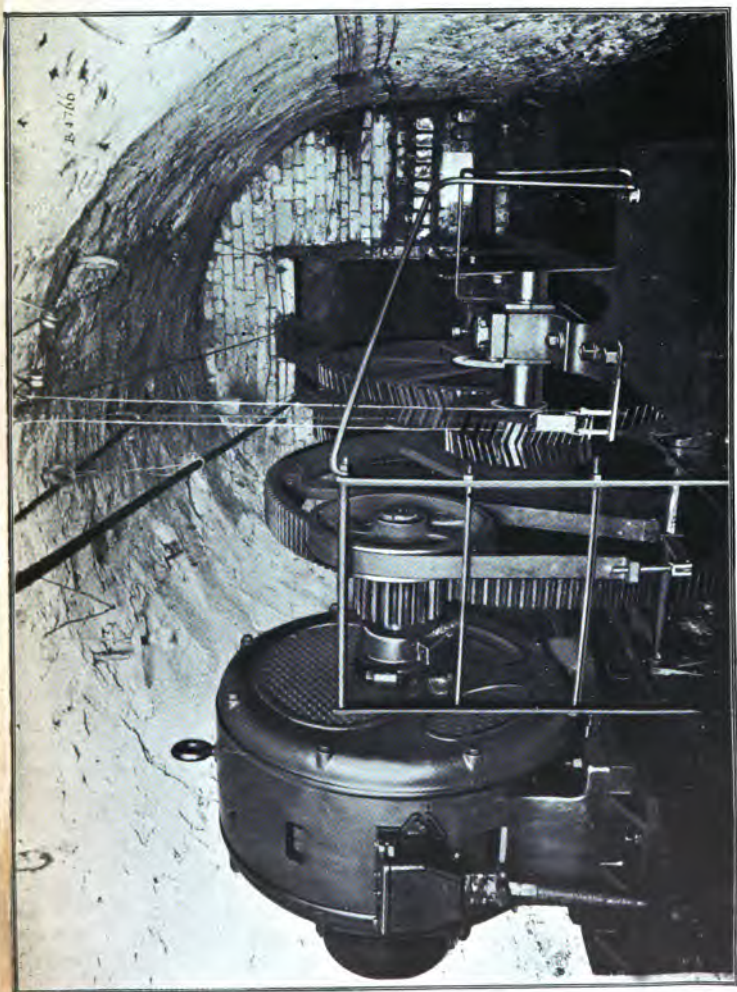
CHAPTER IX

PREPARING COAL FOR THE MARKET

THE operation of preparing the coal for the market is similar to a certain extent to that of preparing the metalliferous ores. The principal difference is that, except where coke is made at the colliery, there is no crushing apparatus, and the crushing in any case is to nothing like as fine a powder as with metalliferous ores.

SCREENING THE COAL

The first operation the coal is subject to is called "screening." In the older collieries, what may be termed single screening was all the preparation the coal went through. The coal screens were sloping grids, very much like the "grizzlies" used in metalliferous mining, and consisted of a number of iron bars held in a framework, and crossed at intervals by other iron bars. The mine wagon on leaving the cage was pushed over to the screen, and tipped up so that the whole of the coal fell down the slope of the screen into a truck below. The small pieces, those below a certain size, fell between the bars, and either into another truck or into a box provided for them, and in some cases on to the roadway. In South Wales a system called "Billy Fairplay" was, and is still, used to a considerable extent. The South Wales coal tends to make a considerable amount of small, which at the time the "Billy Fairplay" machine was introduced was not of much value, and the weight of the fine coal, that which passed through the screen, was deducted from the total weight in the wagon. It should be mentioned that the mine wagon is run over a weighing machine, on its way to the screens, in all cases. The num-



ELECTRICALLY-DRIVEN ENDLESS ROPE HAULAGE IN SOUTH WALES COAL MINE

PLATE XIII

To face page 112



ELECTRIC TROLLEY LOCOMOTIVE IN A GERMAN MINE

PLATE XIV

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Preparing Coal for the Market

ber of the man who has hewed the coal is marked upon the wagon in chalk, and the net weight is credited to him in the colliery books. Where "Billy Fairplay" is employed, the small coal falls into a box under the screens, and is weighed upon a balance weighing machine, a dial over the screens showing the weight ; and this is recorded against him.

Modern coal screens are more carefully arranged, and the mine wagon is made to deliver all its contents to the screen by means of an apparatus called a "tippler." It is run over the weighing machine, on to the tippler, and turned over, the coal being delivered to the screen, and the empty wagon returning to the cage again. Picking belts are also very largely employed in modern collieries. They are very similar to the picking belts described in connection with metalliferous mines. Broad belts consisting of flat plates convey the coal from the neighbourhood of the pit top to a truck which is waiting for it at the end of the picking belt. Boys, and in Lancashire, girls, stand on each side of the belt and pick out the shale and other substances that are not good coal. Picking tables are also occasionally employed, and they are on the same lines as those described in connection with metalliferous mining.

A system of sizing is carried out in modern collieries, the coal being passed through screens of various forms, sometimes circular, sometimes rectangular. The circular screens are made to revolve, and the coal below a certain size passes through their meshes, that above the size for which the screen is set running out at the mouth of the screen on to a belt which conveys it to its own particular truck. Modern inclined coal screens also are arranged to vibrate, so as to separate the coal into the different sizes, the small coal falling through between the bars, the larger being carried over the end of the screen. By means of inclined vibrating coal screens with different sized meshes, and revolving coal screens also with different sized meshes, the coal is separated out into the various sizes, such as peas, nuts, cobbles, and round or large coal.

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COAL WASHING AND COKE MAKING

In modern coal mining a large portion of the smaller coal is washed to get rid of the dirt before it is put on the market, and the whole of the coal that is to be made into coke is very carefully washed for the same reason. In producing coal Nature has not done her work in a very clean manner. Even in the very best seams there is always a large quantity of dirt present, and it is the object of coal washeries to get rid of the dirt. Coal washeries are of various forms, but all are designed to take advantage of the difference in the weight of a small piece of coal and of a small piece of dirt of the same size. In some coal-washing machines the coal to be washed is delivered to an inclined trough, down which it descends ; and during its descent it is subject to the action of a continuous flow of water. In the bottom of the trough, what are virtually scrapers are moving in the opposite direction to that in which the coal and water are moving. The coal and dirt are separated by the action of the water, one lying close to the bottom of the trough and being carried by the scrapers to the top, where it is delivered into a wagon arranged to receive it ; and the other passing over the bottom of the trough with the water. In another form of coal-washing machine there is a large tube, similar to those employed in tube mills, to which the coal to be washed is delivered. The tube is made to revolve, and it is also fixed at an angle with the horizontal. On the inside of the tube is a spiral groove, and the action of the water upon the coal and the dirt separates the two, one falling into the groove and being carried to the top of the tube, while the other is carried out at the bottom of the tube with the water.

In another class of coal-washing machine, boxes containing feldspar broken into small pieces are employed. The coal to be washed is delivered into the boxes ; a continuous stream of water passes through the boxes, and the feldspar and the coal are kept continually in motion by agitators. The result is, the coal and dirt are separated, the dirt being

Preparing Coal for the Market

carried away with the water, and the coal being conveyed to the wagons waiting for it.

The water that is employed to wash the coal still contains a certain quantity of very fine coal dust in suspension ; and in the latest modern treatment the water which has done its work is delivered into large tanks, where the dust is allowed to settle. The water is used over again after the dust has settled, and the dust is employed for firing the colliery boilers.

For coke making, the coal from the washeries is conveyed to crushing machines, and in the most up-to-date treatment the crushed coal is pressed into a cake. It is delivered into what is practically a box, the inside dimensions of which are such that the cake of compressed coal dust formed in it is just the size that will pass into the coke ovens. The coal dust is pressed into a cake by the aid of a rammer, usually worked by an electric motor. When the cake is sufficiently compressed to stand by itself during the time it is being transported to the coke oven, it is pushed out of the box in which it was formed and run along to one of the coke ovens, where a horizontal rammer, worked either by steam, hydraulic power, or electricity, pushes it into the coke oven.

COKE OVENS

The coke ovens of the old days were exceedingly wasteful. Going along in the train through a colliery district where coke was made, the neighbourhood of the coke ovens might be known by the flames which issued from them. The older form of the coke oven was known as the beehive, from its similarity to that object. It was constructed of brick, with a hole in the top, through which the small coal was tipped. When the oven was full it was either ignited, or allowed to ignite, and the gases contained in the coal came away freely through the hole at the top, the residue, which was pulled out from a door in the side, being the substance we know as coke.

Coke is almost pure carbon ; pure coke would be pure carbon. In the making of coke the gases which are present

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with carbon in all coal are burnt, and as far as possible made to carry with them any substances other than carbon. In the old forms of coke ovens no thought was given to the enormous amount of heat that was wasted, by allowing the burning gases to escape at the mouth of the oven. In the modern coke oven the gases are taken charge of ; half their volume is usually employed for heating the ovens, and the remainder is treated very much in the same manner as the gas at an ordinary town's gasworks, the resultant product being employed in gas engines, or under steam boilers. In many modern collieries also sulphate of ammonia is extracted from the coke oven gases, just as it is from town's gas.

Coke oven gases have what is called a high calorific value ; when burnt in air they give off a considerable quantity of heat, and in many collieries at the present time the coke oven gases are used to drive gas engines, which furnish the power for the electricity generating station of the colliery.

CHAPTER X

DIFFICULTIES AND DANGERS OF COAL MINING

THE great danger in connection with coal mining, the one which bulks so largely in the public eye, is that of explosion due to the ignition of a mixture of the gas that is present in the coal with the air of the mine. As explained in a previous chapter, methane, the gas which forms a large portion of the illuminating gas we burn in our houses, is formed from the plants out of which the coal itself is produced, and is imprisoned in the pores of the coal. As the coal is worked, as portions of it are removed, the gases escape, and unless they are diluted below ignition point there is always the danger of an explosion.

The danger of explosion is got rid of in modern coal mines by the perfect system of ventilation which legislation has obliged mine owners to provide. Air is continually passing down the downcast pit along the intake airway, and through all the working places, to the return airway, and thence up the upcast pit.

In the early days of the Coal Mines Regulation Acts, the current of air was created by a large furnace in the neighbourhood of the upcast pit, arranged similarly to that described in connection with metalliferous mines. The furnace provided a column of warm air in the upcast pit, and the difference between the weight of the column of air in that pit and the weight of the column in the downcast pit, provided the necessary force to drive the air current down the downcast pit and through the workings.

In modern mining the fan used to drive the air is nearly always placed at the top of the upcast pit, and exhausts the foul air from the upcast pit and the return airway, air passing down the downcast pit and along the

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intake airway, and through the workings, to replace it. The upcast pit is always covered over, so that the exhaust fan may have its full chance of providing the difference of pressure between the top of the upcast pit and the top of the downcast pit. If the upcast pit was not covered over, the effect of the fan would be largely masked. In working,

the air from the upcast pit passes by way of what is called the fan drift, and thence through the fan to the outer atmosphere. Fig. 55 shows this. As the up-cast pit is also used for hoisting coal and men, either the cover itself is removed when the cage is on the surface, or doors provided for the purpose are opened during the time the cage is being unloaded.

The force required to drive the air through the workings is measured by an instrument called a water gauge. The force employed is very small indeed. Where steam pressures run up to over 100 lbs. per square inch, the air pressures employed in

the ventilating air currents only run at the outside to a few ounces per square inch. Hence the pressure is measured by the weight of a column of water, a square inch in area, that it will support. In British mines 2-inch water gauge is rarely exceeded, though in some modern mines the pressures are being increased. In German and Continental mines pressures of 5-inch and 6-inch water gauge are employed.

As mentioned in a previous chapter, coal dust is also a very dangerous substance about the coal mine. If it is

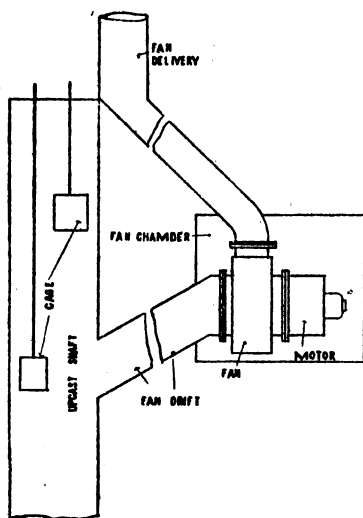


FIG. 55

Diagrammatic sketch showing the arrangement of the fan, fan drift, and upcast shaft at a colliery.

Difficulties of Coal Mining

raised in a cloud and ignited it forms a combustible and explosive mixture. The great danger from coal dust is that with a blown-out shot, a shot which has not been properly tamped, and in which the explosive blows out through the hole into the working face, in place of bringing the coal down, the flames from the explosive raise the coal dust in the neighbourhood into a cloud, and ignite it. If there is a very small percentage of gas present in the dust, the danger of ignition and explosion is very much increased. While less than 5 per cent of gas in air is inexplusive, coal dust with even $\frac{1}{4}$ of 1 per cent is dangerous.

There are several methods of guarding against explosions of coal dust, and there are the usual differences of opinion as to their use. The first method employed, and that is still used to a large extent, is the thoroughly wetting of the coal dust in the neighbourhood of the coal face where the shot is to be fired. This apparently is not always effectual, and it does not provide for the possibility of ignition of an explosive mixture from other causes, and a column of dust being raised with the further disastrous effects. It has been proposed, and in certain collieries the proposal has been carried out, to thoroughly wet the whole of the workings. But this again has been found to have the great disadvantage that in deep mines, and in cold weather on the surface, the air entering the mine being warmed by contact with the warm strata below ground, and having its capacity for moisture largely increased, rapidly licks up whatever moisture may have been provided, so that the problem of keeping a mine of large area continually moist is a very difficult one.

The latest method that has apparently been successful is the strewing of the roads with unflammable kinds of stone dust.

SPONTANEOUS COMBUSTION

Another very serious trouble to which many coal mines are subject is that known as spontaneous combustion: the ignition of the coal usually without warning, and without any apparent cause. Warning is given to experienced miners by the presence of "gob stink," the mining term

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given to the peculiar smell which usually precedes an outbreak. Fires of very serious character and embracing large areas often occur through spontaneous combustion, in a few cases leading to the abandonment of the mine, and in all cases to the loss of a considerable quantity of the coal. The fires arise in many cases in the "gob," or "goaf," the waste ground from which the coal has been removed, and in other cases in the mass of the coal itself. The cause is now believed to be the absorption of oxygen gas from the air, by the coal, followed by the oxidation of the coal. The temperature is found to rise at an increasing rate as the rate of absorption of oxygen increases, while this increases as the temperature rises. So far no remedy for the trouble has been found, except digging out the fire when it is discovered, in some cases, and "stopping off," practically stopping the supply of air to the burning mass in others. The author has suggested the use of refrigerating apparatus to keep the temperature of the masses of coal and of the goaf below the critical figure.

Similar troubles arise with stacks of coal on the surface, in gasworks' yards, and in cargoes of coal on board ship.

WATER, AND HOW IT IS DEALT WITH

Water is also met with largely in coal mines, though in most of them it is not so troublesome as in metalliferous mines. Its presence is due to the same reasons as in the case of metalliferous mines. It percolates through from water-bearing strata, and in the course of the workings springs are often tapped. Pumping is carried on in exactly the same manner, and by the same forms of pumps as with metalliferous mines. Small three-throw ram pumps, or centrifugal pumps, electrically driven, are employed to pump the water from what are called the "dip workings," the lower parts of the mine, to the "sump," the space at the bottom of the shaft below the cage, virtually a tank into which the water from the shaft, and any other water that may be pumped from the workings, drains. The water from the "sump" is pumped to the surface by pumps provided for it: sometimes worked by steam, sometimes

Difficulties of Coal Mining

by compressed air, but in modern mines nearly always by electric motors.

FALLS OF ROOF

One of the greatest troubles in all mines is the danger from falls of roof. It has been aptly pointed out by miners' leaders that while a big explosion carries off sometimes several hundred lives at once, and the public are shocked by the result, very few hear of the constant dribble of lives that takes place almost daily, in almost every mine in every part of the world. In every mining district, if the papers are perused, it will be found that in some mine or other, one or more men have been either hurt or killed by a fall of rock, usually in the working places. This, of course, is one reason why only skilled miners, men of experience, should be employed in working at the coal face. Skilled miners know the sounds when the roof is likely to give way, and they can provide for it. The remedy is, of course, plenty of timber, and the timber carefully placed to support the roof. The use of coal-cutting machines is claimed to lessen the danger from falls of roof, as the face advances more regularly, and can be more carefully timbered. The electrically driven machine also is claimed to be better than the compressed air driven machine, as it makes less noise, so that there is a better chance of hearing the warning sounds emitted by the roof.

CHAPTER XI

THE LIGHTING OF MINES

IN the early days of mining the tallow candle was the universal light, and it remains so to a large extent in many of the metalliferous mines to the present day. The tallow candle gave way to small lamps burning paraffin and other oils. In modern coal mines, however, naked lights—naked candles and naked lamps—have gradually been displaced by the miner's safety lamp. The property upon which the safety lamp depends was discovered by Sir Humphry Davy, though it was some years before the principle was adopted for mining work. If a piece of fine gauze is held against a flame until the gauze becomes red hot, it is impossible to ignite gas on the other side of the gauze, and hence a lamp whose wick was burning inside of a cylinder of gauze was protected from the danger of explosion. But with modern ventilating air currents demanded by the Coal Mines Regulation Acts, the velocity at which the air current passes has destroyed the safety of the old form of Davy lamp. A single gauze lamp is no longer safe in an air current charged with gas; it very quickly explodes inside of the lamp, putting the lamp out, and possibly igniting gas. The modern safety lamp has a small cylinder of very thick glass to protect the flame, and to allow the light to escape. Above the glass are two or more thicknesses of gauze, protected by a bonnet of iron. There are small holes protected by gauze in the lower part of the lamp, and other small holes protected by gauze above the bonnet, the current of air required to furnish the oxygen enabling the oil in the wick to burn, passing through the lamp by way of these gauze-protected holes. Plate XVI shows a modern safety lamp.



SCENE AT PIT BOTTOM, SNOWDOWN COLLIERY, KENT

PLATE XV

To face page 122



PLATE XVIA

The lamp which won the £600 prize



XVI
A MODERN SAFETY LAMP

ELECTRIC MINER'S LAMP, C.E A.G.

To face page 123

The Lighting of Mines

Great care is taken in all modern mines to prevent miners from opening their lamps. The safety lamp unfortunately has a trick of being very easily extinguished, and hence the temptation to a man who may be a long distance from the lighting station, which is provided in each colliery underground, to open his lamp and relight by the aid of a match. In some cases the lamps are locked by an iron pellet, which can only be withdrawn by the aid of a powerful magnet that is kept at the lamp station, and the lamp itself is ignited by an electric spark furnished by a current from a battery also kept at the lamp station.

In spite of these precautions the modern safety lamp is strongly suspected of having caused some of the explosions that have occurred during recent years.

The oil safety lamp is steadily giving way to the electric safety lamp, one form of which is shown in Plate XVIIA. It consists of a very small incandescent lamp, a small edition of those used for lighting houses, offices, etc. whose current is furnished by a small secondary battery, carried in the case upon which the small incandescent lamp is mounted. The incandescent lamp is protected by a thick glass, in the same manner as the flame of the ordinary safety lamp. A switch, carried on the lamp, allows the current to be cut off from the lamp at will. Very great improvements have recently been made in electric safety lamps, largely owing to the offer of a substantial prize for a lamp fulfilling certain conditions.

THE DETECTION OF GAS

The electric safety lamp has one important defect, as compared with the candle, the open paraffin lamp, and the safety lamp: it will not denote the presence of gas. Open lights, giving light by the aid of combustion, and safety lamps, have a double office, viz. to furnish light, and to indicate the presence of gas. The flame of both the candle and the safety lamp elongates when gas is present; by drawing the wick of the safety lamp down, and by the aid of long practice and experience, the miner is able to tell approximately the percentage of gas present. With some of the later forms of miner's lamps, and with men carefully

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trained, it is possible to tell the presence of very small percentages of gas, and approximately of the quantities.

In the early days of mining the old practical miner, as mentioned in a previous chapter, knew of the presence of gas by the elongation of the flame of his candle.

There is nothing at present in connection with the electric safety lamp that will show the presence of gas. Several attempts have been made to produce an indicator, by the aid of what is called the "catalytic" action of gas, when present, upon heated platinum; but so far no satisfactory indicator has been produced.

For the general lighting of all mines, both coal and metaliferous, the electric incandescent lamp reigns supreme. For underground, in the neighbourhood of the pit bottom, incandescent lamps of 8 c.p. up to 100 c.p. are employed. No fixed lights are usually employed in mines, except in the neighbourhood of the pit bottom and in the engine houses. At the face of the coal safety lamps are always used.

On the surface, the engine houses, offices, the pit head, the neighbourhood of the shaft are lighted largely by incandescent electric lamps of various powers. The arc lamp is employed sometimes on the pit bank, and very frequently for lighting the colliery sidings. The mercury vapour arc lamp is employed for lighting the coaling screens, and particularly for the picking belts. The light furnished by both the incandescent electric lamp and the ordinary arc lamp does not enable the pickers to distinguish between coal and shale; the bluish light furnished by the mercury vapour lamp does.

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